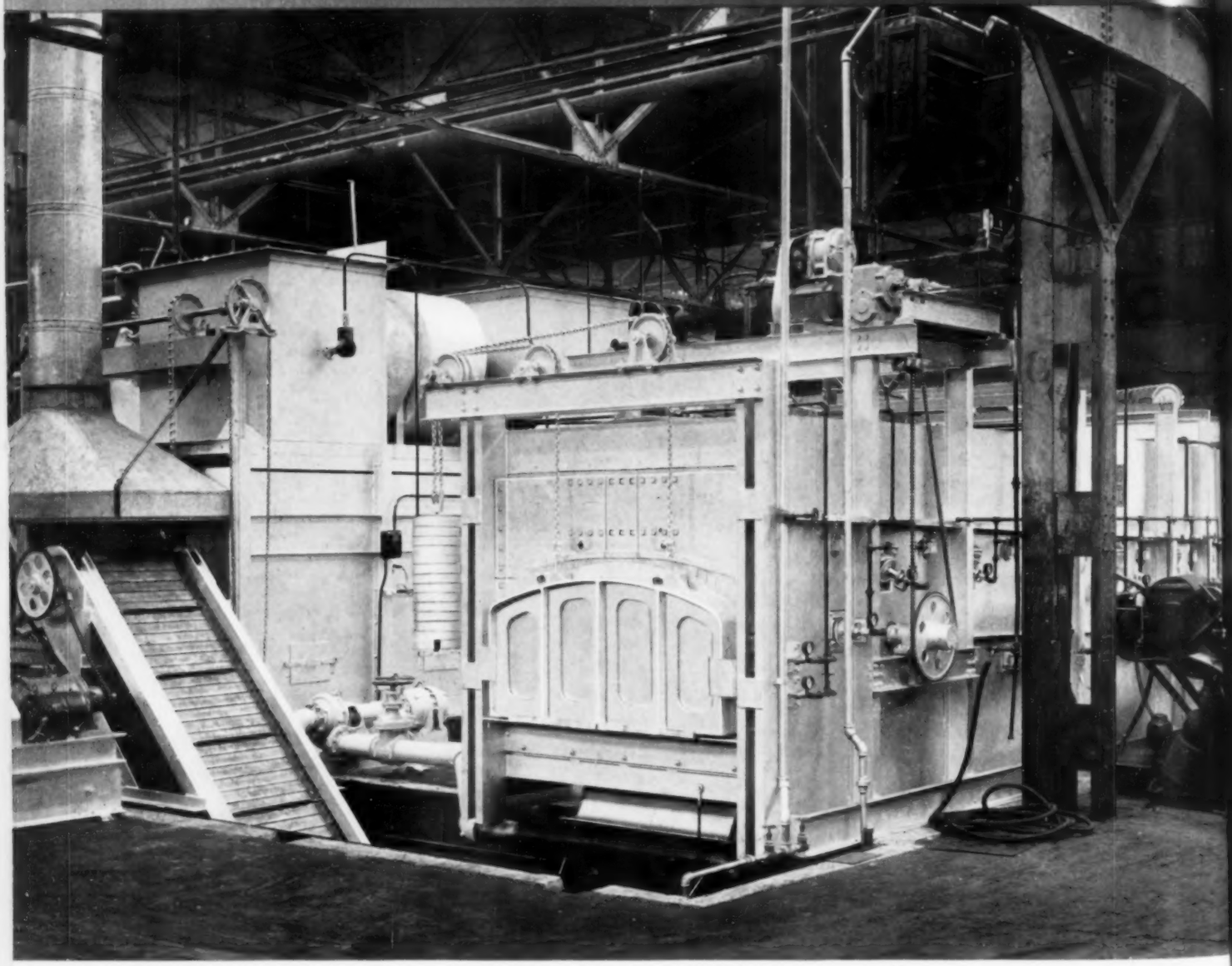
# METAL PROGRESS

AMERICAN SOCIETY FOR METALS

1 9 MARCH 3 8

# TOUGHENING THE SOLES OF A TRACTOR'S FEET



● Abrasive action on tractor shoes and grousers from the varied terrain over which it must operate, plus the severe stresses to which the linkage of the tractor caterpillar tread is exposed, combine to set up requirements for steel analysis and heat treatment that are necessarily exacting. For this reason heat treating equipment must be built to the highest standards possible.

Here is an SC gas-fired hardening and an SC gas-fired air-draw furnace in the plant of a nationally known tractor builder. Track shoes, weighing from 4.85 to 40.25 pounds, and grousers weighing from 3.87 to16.5 pounds are continuously conveyed through the hardening furnace; automatically quenched and conveyed to the air draw furnace where they are drawn to the desired hardness.

Surface Combustion Engineers design and build special furnaces for the most exacting demands of industry. The same engineering experience and quality of both material and workmanship is back of all SC *standard rated* gas-fired furnaces available in more than 200 different sizes.

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*Builders of* ATMOSPHERE FURNACES and HARDENING, DRAWING, NORMALIZING, ANNEALING FURNACES for CONTINUOUS or BATCH OPERATIONS

Published by the American Society for Metals

# Metal Progress

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# WHAT TOOK US *Years* ... WILL TAKE YOU *Minutes*

● You can't learn all of the known intricacies of steel in a few minutes. It takes years . . . years of research and experimentation in the laboratory . . . years of work in every class of industry with manufacturers of every type of steel-using equipment . . . long years which cost many millions of dollars.

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# AN INVITATION

TO MEMBERS AND FRIENDS,
American Society for Metals:

Nine years ago the first Western Metal Congress was held in Los Angeles. In 1931 the event was repeated with great success in San Francisco. Not again until this year, when the Western Metal Congress and Exposition opens in Los Angeles March 21, has another metal congress been sponsored by the American Society for Metals on the West Coast.

Industry on the Coast, however, has been far from stagnant during the intervening years. And in the innumerable fields of industry, both large and small, developing in this great section of the country, the use of metals is growing by leaps and bounds. With this growth comes need for more knowledge — knowledge about properties of metals at high temperature and high pressure, at low temperature, under stresses of all kinds; knowledge about fabrication — forming, machining, welding; about the myriad different types of alloys and their qualifications.

This industrial growth is reflected in the growth of the American Society for Metals. In 1929 and 1931 there were only two chapters of the Society west of the Mississippi. Their combined membership totaled about 300. Now the original Los Angeles and Golden Gate Chapters have been reinforced by the Oregon, Puget Sound and Texas Chapters, with a total additional membership of over 700.

Theme of the Western Metal Congress will be "Metals in Industry." The technical papers will be directed toward the uses of metals in those manufacturing fields prominent in the West. Sessions will be devoted to aviation, the oil industry, chemical industry, mining, foundry practice, and machinability of metals. The American Society of Mechanical Engineers will hold its spring meeting during the Congress, with sessions on applied mechanics, petroleum, hydraulics, aeronautics, and machine shop practice. The Pacific Coast sections of the American Welding Society, also meeting this same week, will feature the welding of large pipe for water and gas, well-casing strings, machinery, and structural frames.

Simultaneous with the technical sessions of the Congress, listed on the next page, will be the Western Metal Exposition, held in the Pan-Pacific Auditorium. Like the National Metal Expositions held annually in the East, this show will exhibit the latest developments in products and processes, many of them in actual operation. Those who have attended the ⊕ annual conventions will know that this event is one which no progressive executive or engineer can afford to miss.

Altogether 18 technical societies are cooperating in the Congress and Exposition — it is truly a joint enterprise. In addition to the A.S.M., A.S.M.E., and A.W.S., they include the Mining and Metallurgical Engineers, Civil Engineers, Electrical Engineers, Aeronautical Engineers, Foundrymen, Chemists, Automotive Engineers, Purchasing Agents, the Petroleum Institute, American Society for Testing Materials, Chamber of Mines and Oils, Metal Trades Association, Mining Association of the Southwest, and the Pacific Coast Gas and Electrical Associations.

Another attraction which the Congress offers is the trip to the Coast itself. To make this ideal winter vacation doubly inviting, the American Society of Mechanical Engineers has arranged a special all-expense tour starting from Chicago and including stopovers in New Mexico and at Grand Canyon. After the week of the Congress, return by boat (which is optional), with stops in Mexico, Panama and Havana, completes a perfect month.

Those who live in the western states will need no urging to attend. There may be some who live in the East, however, who feel that such a lengthy trip would not be warranted merely to attend an event which is given annually in the East. To them it can be said that the **Western** Metal Congress will be different. The problems to be considered are different and an emphasis will be put on the best way to do things with metals. Here is an opportunity to gather information, both technical and commercial, which, by virtue of its divergence from the usual convention fare, should be invaluable to executives and engineers from every part of the country.

G. B. Waterhouse
President

THE AMERICAN SOCIETY FOR METALS

TECHNICAL PROGRAM

# *Western Metal Congress*

## Monday, March 21, 1938

*Morning, 9:30 A.M. at Biltmore Hotel*

Tin Plate in the Canning Industry, by B. W. Gonser, Research Engineer at Battelle Memorial Institute, Columbus, Ohio.

Application of Metals in the Chemical Industry, by F. L. LaQue, Development Engineer for International Nickel Co., New York City.

Fabrication and Uses of the Hardenable Stainless Steels Containing From 0 to 15% Chromium, by Bradley Stoughton, Dean of Engineering at Lehigh University, Bethlehem, Pa.

Fabrication and Uses of Stainless Steels Containing 18% Chromium and Over, by V. N. Krivobok, Associate Director of Research, Allegheny Steel Co., Brackenridge, Pa.

*Afternoon, 2:00 P.M. at Pan-Pacific Auditorium*

Testing for Wear, by Fred Arnold, Metallurgist for Kobe, Inc., Los Angeles.

New Developments and Applications of Hard Facing Material, by C. C. Pendrell of Haynes-Stellite Co., Kokomo, Ind.

High Tensile Steels for Light Weight Construction, by A. F. Stuebing, Railroad Mechanical Engineer for United States Steel Corp., New York City.

*Evening, 8:00 P.M. at Pan-Pacific Auditorium*

A. Allan Bates, Manager of Chemical and Metallurgical Dept. of the Research Laboratory, Westinghouse Electric & Mfg. Co., Pittsburgh, will present the first of a series of five educational lectures on "Fundamentals of Ferrous Metallurgy," open to all interested.

## Tuesday, March 22, 1938

*Petroleum Day*

*Morning, 9:30 A.M. at Biltmore Hotel*

Metals Used in Petroleum Production, by Harry W. McQuaid, Metallurgist for Republic Steel Corp., Cleveland.

Metals Used in Pipe Line and Pipe Line Station Construction, by L. F. Scherer, Assistant Chief Engineer for Texas Pipe Line Co., Houston.

Theory and Practice in Pipe Protection, by Gordon N. Scott, Pipe Line Technologist, Los Angeles.

Valves for the Petroleum Industry, by George F. Scherer, Chief Metallurgist for Merco-Nordstrom Valve Co., Oakland, Cal.

*Tuesday Afternoon, 2:00 P.M.*

High Temperature Strength of Steels, by R. L. Wilson, Metallurgical Engineer for Climax Molybdenum Co., Canton, Ohio.

High Temperature Characteristics of Steels as Revealed by the Stress-Rupture Test, by W. G. Hildorf, Chief Metallurgical Engineer for Timken Roller Bearing Co., Canton, Ohio, A. E. White and C. L. Clark of the Dept. of Engineering Research of University of Michigan, Ann Arbor.

Typical Failures of Still Tubes in Refineries, by E. C. Wright, Chief Metallurgist of National Tube Co., Pittsburgh, and H. Hobart, Metallurgist of its Ellwood Works.

Alloy Steel Tubing for Oil Heaters, by R. L. Wilson, Metallurgical Engineer for Climax Molybdenum Co., Canton, Ohio.

*Evening, 8:00 P.M.*

A. Allan Bates will present the second of his series of educational lectures.

## Wednesday, March 23, 1938

*Simultaneous Sessions at Biltmore Hotel*

Metals Used in the Production of Mining Equipment, by G. B. Waterhouse, Professor of Metallurgy at Massachusetts Institute of Technology, Cambridge.

The Use of Metals in Pyrometallurgy, by R. S. Dean, Chief Engineer, and M. W. von Bernewitz, Assistant Engineer, U. S. Bureau of Mines, Washington, D.C.

Metals Used in the Dredge Mining Industry, by C. M. Romanowitz, Sales Manager, and Herbert A. Sawin, Assistant Sales Manager for Yuba Manufacturing Co., San Francisco.

Electrolytic Manganese: the First Step in a Program for the Establishment of an Electrometallurgical Industry, by R. S. Dean, Chief Engineer of the Metallurgical Division, U.S. Bureau of Mines, Washington, D.C.

*Aeronautical Program*

The Use of Metals in the Aircraft Industry, by J. R. Goldstein of Research Dept. of Douglas Aircraft Co., Inc., Santa Monica, Cal.

Magnesium Alloys and Their Use in Aircraft, by Arthur W. Winston, Metallurgist for Dow Chemical Co., Midland, Mich.

Design and Production of Aluminum Alloy Aircraft Forgings, by A. A. Handler, Manager, and L. W. Davis of the Forging Division, Aluminum Co. of America, Cleveland.

Engineering Alloy Steels (S.A.E. Specifications), by Bradley Stoughton, Dean of Engineering at Lehigh University, Bethlehem, Pa.

# TECHNICAL PROGRAM

# *Western Metal Congress*

*Wednesday Afternoon, 2:00 P.M. at Pan-Pacific Auditorium*

Forgings for Aircraft, by Waldemar Naujoks, Chief Engineer of Steel Improvement & Forge Co., Cleveland.

Stainless Steel for Aircraft, by Carl de Ganahl, President of Fleetwings, Inc., Bristol, Pa.

X-Ray Inspection of Aeronautical Materials, by Tom A. Triplett of the Triplett & Barton Laboratories, Burbank, Cal.

*Evening, 8:00 P.M. at Pan-Pacific Auditorium*

Doctor Bates presents the third of his educational lectures on "Fundamentals of Ferrous Metallurgy."

## Thursday, March 24, 1938

*Morning, 9:30 A.M. at Biltmore Hotel*

Carbon and Low Alloy Tool Steels, by J. P. Gill, Chief Metallurgist of Vanadium-Alloys Steel Corp., Latrobe, Pa.

Controlled Furnace Atmospheres, by E. E. Thum, Editor of Metal Progress, Cleveland.

Hardenability as It Affects Heat Treated Parts, by M. A. Grossmann, Director of Research for Carnegie-Illinois Steel Corp., Chicago.

High Speed and High Carbon, High Chromium Die Steels, by J. P. Gill, Chief Metallurgist of Vanadium-Alloys Steel Corp., Latrobe, Pa.

*Afternoon, 2:00 P.M. at Auditorium*

*Machinability Program*

Making Steels Free Machining, by J. D. Armour, Chief Metallurgist for Union Drawn Steel Co., Massillon, Ohio.

Machinability of Alloy Steels, by Harry W. McQuaid, Metallurgist for Republic Steel Corp., Cleveland.

Machinability of Ferrous Castings, Including Malleable, Gray Iron and Steel, by E. K. Smith, Metallurgist for Electro Metallurgical Co., Detroit.

Machining of Cast and Wrought Aluminum Alloys, by W. A. Dean, Research Laboratories of Aluminum Co. of America.

*Late Afternoon, 5:00 P.M. at Auditorium*

The Exposition closes for the day at 6:00 P.M. Therefore Dr. Bates will deliver the fourth of the lectures on "Fundamentals of Ferrous Metallurgy" at 5:00 P. M.

*Friday Evening, 7:00 P.M. at Biltmore Hotel*

Dinner-Dance and Entertainment at the Biltmore Bowl for all members of the cooperating societies and exhibitors.

## Friday, March 25, 1938

Foundry Programs; all papers to discuss
(a) New Technique in Casting and
(b) New Uses for Modern Castings

*Morning, 9:30 A.M. at Biltmore Hotel*

Improvements in Steel Castings by Moderate Alloying and Heat Treatment, by F. A. Melmoth, Vice-President of Detroit Steel Casting Co., Detroit.

Nickel Steels and Irons, by F. J. Walls, Development Engineer for International Nickel Co. at Detroit, and T. N. Armstrong of the Development and Research Division of International Nickel Co., New York City.

Chromium Steel and Iron Castings, by E. K. Smith, Metallurgist for Electro Metallurgical Co., Detroit.

Molybdenum Steels and Irons, by W. P. Woodside, Vice-President of Climax Molybdenum Co., Detroit.

*Afternoon, 2:00 P.M. at Pan-Pacific Auditorium*

Copper Alloys in the Foundry, by William Romanoff, Technical Superintendent and C. O. Thieme, Chief Metallurgist for H. Kramer & Co., Chicago.

Recent Improvements in the Art of Casting Aluminum Alloys, by H. J. Rowe of the Technical Dept., Castings Division, Aluminum Co. of America, Cleveland.

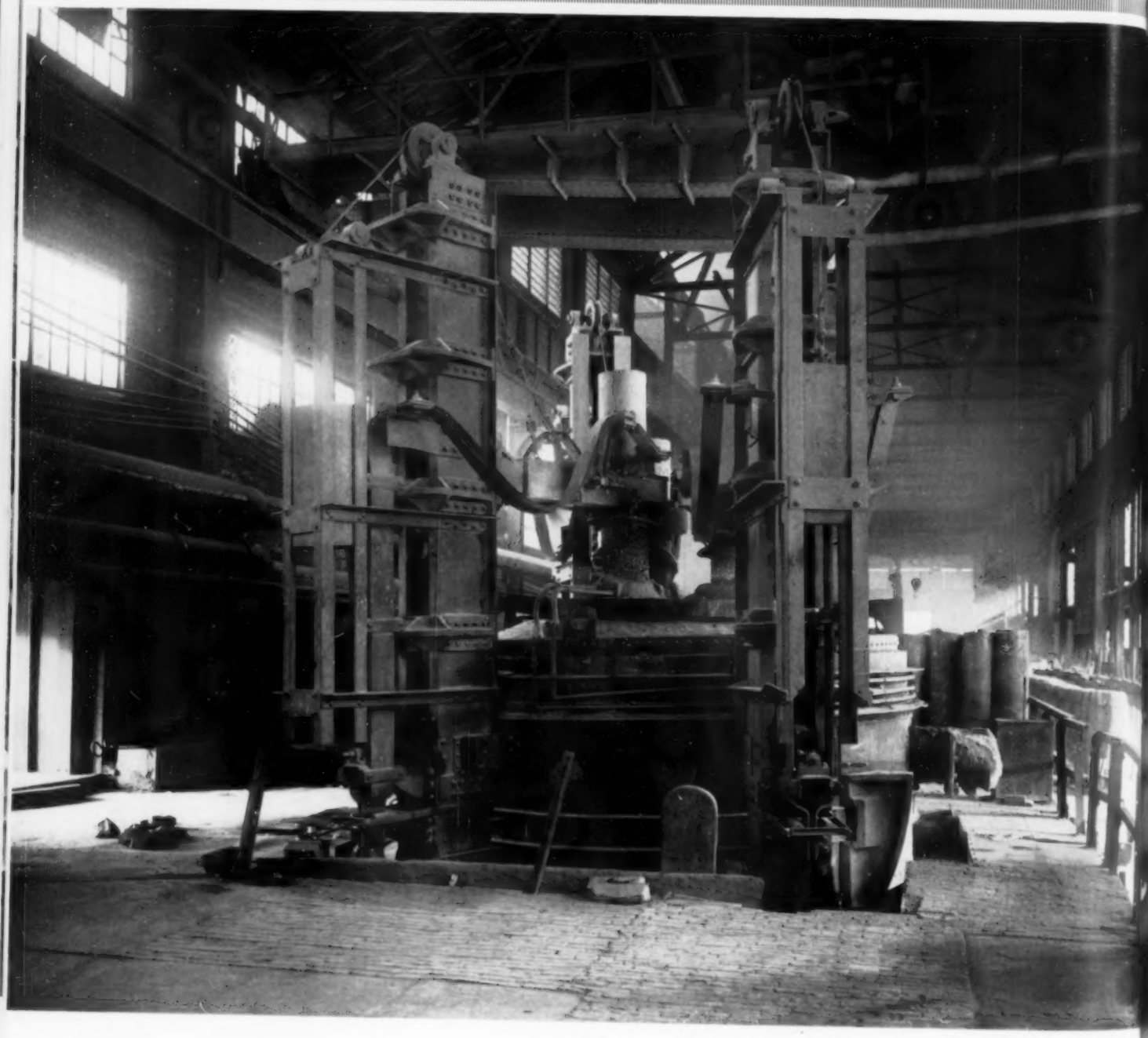
The Improvement in Zinc Alloy Die Castings—an Industrial Achievement, by W. W. Broughton, Engineer for New Jersey Zinc Sales Co., New York City.

Flame Hardening, by G. V. Slottman, Research Engineer for Air Reduction Sales Co., New York City.

*Evening, 8:00 P.M. at Pan-Pacific Auditorium*

The last of the series of five lectures on "Fundamentals of Ferrous Metallurgy" by A. Allan Bates.

*Evening, 10:30 P.M.; Exposition Closes*



A Metallurgical Pioneer

*This 10-Ton Girod Furnace, Basic Lined, Produced Alloy and Carbon Toolsteel at Bethlehem Between 1912 and 1926*

# Making Toolsteels

## in electric arc furnace

This third article in a series entitled "Toolsteels—Past and Present" considers the fundamental advantages of refining under a reducing atmosphere as compared with the oxidizing conditions inseparable with a fuel-fired furnace. Essentials of the double-slag process are also given

INTRODUCTION OF THE ELECTRIC ARC FURNACE IN commercial steel manufacture has exerted a profound influence upon the production of the finer grades of steel, particularly those of higher alloy content.

Although many chemists and metallurgists had previously conducted small experiments in the electric furnace, Sir William Siemens, in 1882, was probably the first to make use of it in metallurgical work for commercial purposes. He melted some 20 lb. of steel in an arc furnace constructed four years previously. Then came the furnace of E. H. and A. H. Cowles, a resistance type of furnace invented in 1885 for the production of aluminum alloys and for a variety of other purposes. A year later Paul Heroult and C. M. Hall patented processes for the production of aluminum, using submerged electrodes. In 1892 T. L. Willson, aided by data gathered by Moissan in his classical experiments, made calcium carbide in an electric furnace, and at about the same time E. G. Acheson made carborundum in a resistance furnace. Two years later Capt. Ernesto Stassano of Italy patented an electric furnace for smelting iron ores, and demonstrated the working of his new process in 1898.

As a result of the work of Stassano and of the successful manufacture of ferro-alloys in the electric furnace, steel was next made in France by Heroult and in Sweden by Kjellin under patents taken out in 1900. In 1906 experiments with reduction of iron ores in the electric furnace were conducted by the Canadian Government and by Grönwall, Lindblad, and Stålhane in Sweden. The electric iron smelting industry is now well established in the last mentioned country.

**By H. C. Bigge**
Supt., Tool Steel Dept.
Bethlehem Steel Co.

### Electric Furnaces in United States

The first electric arc furnace in the steel industry in the United States was installed by Halcomb Steel Co. of Syracuse, N. Y., in 1906; actual operation began on April 5 of that year under general direction of the late John A. Mathews. This was a 4-ton single-phase furnace and was intended for refining only, as the preliminary melting was done in a tilting open-hearth furnace; it was not considered possible to use electricity for the initial smelting. For some time this was the only electric furnace in this country, but now several hundred are in use, ranging from ¼ ton up to 100 tons.

The electric arc furnace has contributed very materially to the development of alloy steels, not only directly through its adaptability for producing quality alloy

*One of the First Heroult Furnaces to Make Toolsteel in the United States Was Installed in the Fall of the Year 1908 in the Form of This 2¼-Ton Heroult Three-Phase Furnace. Melting time averaged about 10 hr., 105 lb. of 8-in. electrodes was consumed per heat, and about 1000 kw-hr. of electrical energy per net ton of steel*

steels, but also indirectly in the production of ferro-alloys for use in the making of these very steels. Its use has spread very rapidly due to the availability of cheaper power, the ability to lower the phosphorus and sulphur content of the steel produced, and the accurate control of either oxidizing and reducing conditions as desired in the furnace.

### Use for Ferro-Alloys

While it may have been possible to use the Goldschmidt thermit process in the production of all of the various ferro-alloys now employed in making alloy steels, it is probably safe to say that the alloys produced in the electric arc furnace are freer from incidental elements (other than carbon) and non-metallic impurities. It is, therefore, quite evident that the electric arc furnace has played this indirect but important part in the development of alloy steels.

Before describing the electric furnace operation it may be in order to show wherein the basic openhearth and basic electric furnace operations differ.

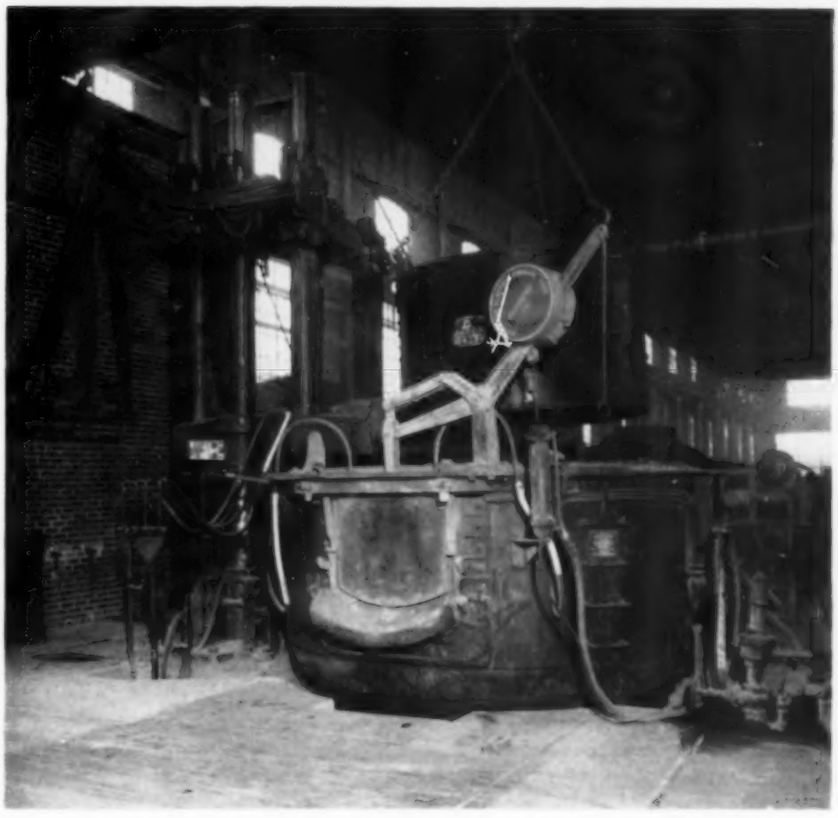
1. In the openhearth operation a large percentage of the carbon, silicon and other readily oxidizable elements are lost, due to reaction with the oxidizing gases which must be present if the fuel is to be utilized efficiently, or if a sufficiently high temperature is to be obtained. As the source of heat in the electric furnace is not dependent on the combustion of either a liquid or gaseous fuel, the loss of these oxidizable elements is consequently lessened, and more accurate control is therefore made possible.

2. Phosphorus can be reduced to the desired point during the oxidizing period in the electric furnace; the slag containing the phosphorus which has been eliminated from the steel can then be skimmed off, thus removing the possibility of having phosphorus revert to the metallic bath. In the openhearth process it is possible, during the oxidizing period, to reduce the phosphorus content of the metal to the same extent as in the electric furnace, but there is always danger of reversion of the phosphorus when the bath is deoxidized. The use of a tilting furnace and two slags might eliminate this possibility, but there are certain objections to the use of a tilting openhearth furnace, one of the most serious of which is the considerable difficulty of making a really tight connection between the furnace proper and the two stationary end-portions.

3. Sulphur which is partly removed during the oxidizing period may be brought down further in the electric arc furnace — to below 0.015% if desired — during the reducing period. It is eliminated by the formation of either calcium sulphide or silicon sulphide, or both. In the basic openhearth furnace it is possible to lower the sulphur to approximately 0.025%, relatively much higher than the figure given above for the electric furnace. This can be accomplished by using a low sulphur fuel, a very limy slag, a high manganese pig iron, or manganese added to the charge (when the

manganese specified for the finished steel will permit it).

4. In the openhearth furnace it is necessary to maintain an oxidizing condition in order to retain phosphorus in the slag. Deoxidation of the steel bath must therefore be accomplished by introducing alloys with greater affinity for oxygen than that of iron. Among these elements are manganese, silicon, aluminum, vanadium, titanium, calcium, zirconium and magnesium. It is also important that the products of deoxidation be readily fusible and that they coalesce and rise into the slag. It is possible that a tilting openhearth furnace would solve this problem of deoxidation, through the use of a second slag which may be practically neutral. This would approach the conditions prevailing in the electric furnace. In the operation of the electric furnace it is the general practice, after removing the oxidizing slag, to make either a neutral or a strongly reducing slag. In other words, in the electric furnace the atmosphere and the slag can both be utilized to aid the other elements in deoxidizing the steel bath. In the openhearth, however, it is necessary to rely on deoxidizers exclusively.



*Modern 'Lectromelt Furnace (6-Ton Capacity) Has Removable Roof, so Charge Can Be Placed by a Drop-Bottom Bucket or Magnet*

## Manufacture of Electric Steel

In the operation of the basic arc electric furnace we have two distinct periods, first an oxidizing period which induces the melting operation and second, a reducing period in which the deoxidizing slag (termed "white" or "falling") is peculiar to the arc furnace. There may be variations in the practice during each of these stages, depending on the character of the charge and the product desired. This will be shown in the following description of current practice.

*Oxidizing Period* — The degree of oxidation can be varied as required. It may be that oxidation is not desirable (as shown by first slag and metal tests in the first table), in which case the slag will be made reducing without "slagging off" as soon as the melting operation is complete. Any oxidation of the metal is due to the oxide (scale and rust) charged with the scrap and iron, plus that resulting from infiltration of air. This practice is generally used in melting scrap rich in alloys and sufficiently low in phosphorus so that no steps to remove a part of this impurity are required. The amount of carbon and manganese in the charge is so regulated that the content of these elements in the bath, when ready to be tapped, is equal to, or slightly below that required in the finished steel. On the other hand, it may be desirable (and most frequently is) to produce a definitely oxidizing slag which will lower the carbon content of the bath to the desired point and which will eliminate the excess phosphorus and a portion of the

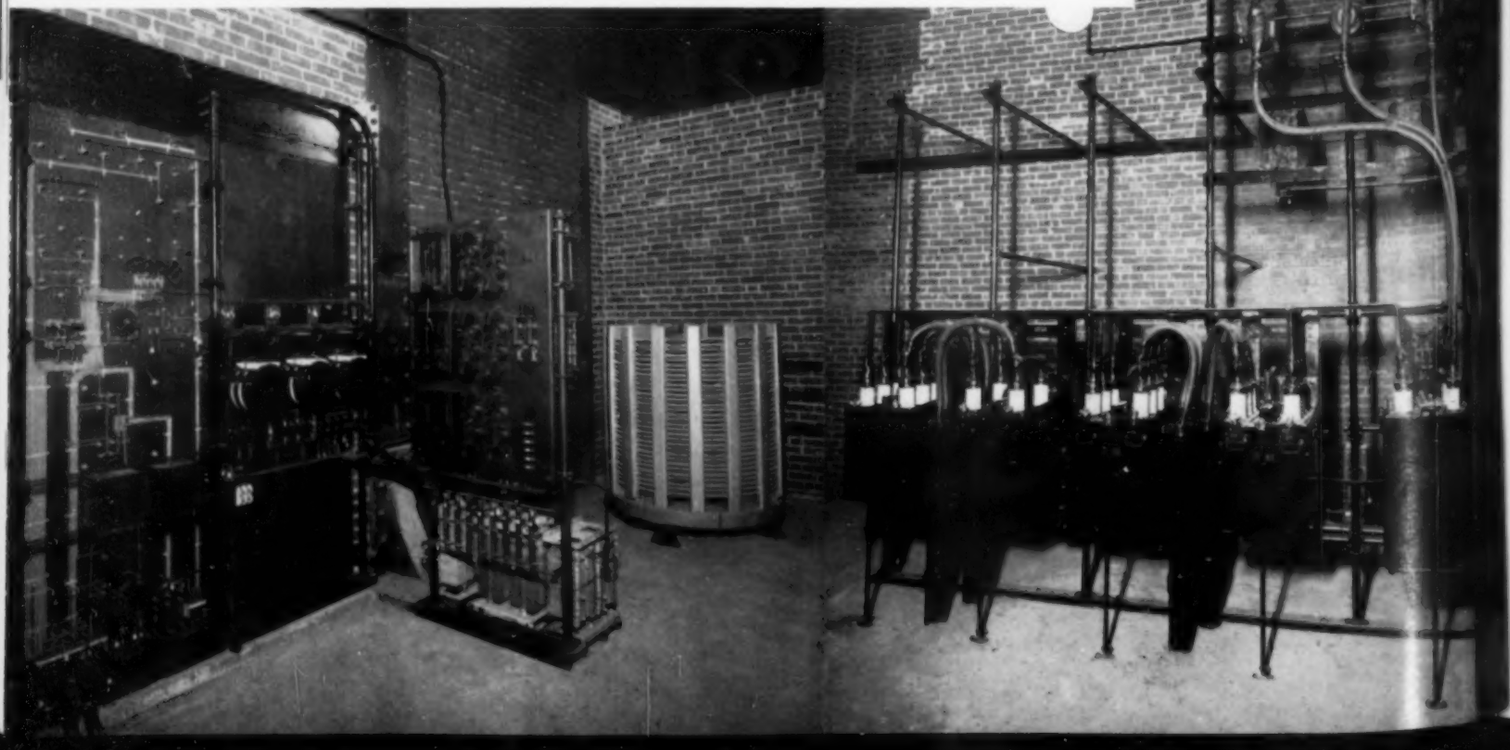
**Metal and Slag Tests for High Speed Steel**

| Metal | | | Slag | | |
|---|---|---|---|---|---|
| Element | Test No. 1 | Test No. 2 | Compound | Test No. 1 | Test No. 2 |
| C | 0.68 | 0.74 | C | 0.15 | 0.50 |
| Mn | 0.19 | 0.22 | MnO | 0.19 | 0.05 |
| P | 0.014 | 0.016 | $P_2O_5$ | 0.010 | 0.010 |
| S | 0.016 | 0.012 | $SO_3$ | 0.45 | 0.46 |
| Si | 0.12 | 0.26 | $SiO_2$ | 20.18 | 23.68 |
| Ni | 0.10 | 0.10 | | | |
| Cr | 2.78 | 4.27 | $Cr_2O_3$ | None | None |
| W | 18.32 | 18.87 | $WO_3$ | None | None |
| V | 0.81 | 1.19 | $V_2O_5$ | 0.52 | 0.07 |
| | | | $Al_2O_3$ | 2.18 | 4.76 |
| | | | CaO | 67.69 | 66.03 |
| | | | MgO | 7.78 | 3.64 |
| | | | FeO | 0.85 | 0.80 |
| | | | Color | White | White |
| | | | Nature | Disintegrating | Disintegrating |

sulphur (as shown by slag and metal tests in the second table). In this case, when the phosphorus and carbon have both been brought down to the desired point, the first slag is removed and a second slag is formed. As the character of the raw materials is usually such that elimination of a certain percentage of phosphorus is necessary, this is the practice that is more generally used.

*Reducing Period* — When the desired carbon and phosphorus contents have been attained, the oxidizing slag is removed by an operation known as "slagging," leaving the metal temporarily skimmed and exposed to the atmosphere of the furnace. The second slag is made up by charging calcined lime, fluorspar and finely pulverized ferrosilicon in the proper proportion onto the bare metal. The chief functions of this reducing slag are to deoxidize the metal, to bring down the sulphur content of the bath, to protect the metal from oxidation, and to prevent absorption of carbon.

The type of reducing slag utilized depends on the kind of steel produced. In the manufacture of high carbon toolsteel, high carbon alloy steel, or high speed steel, it is common practice to produce a carbide slag — that is, a slag to which a generous quantity of finely pulverized carbonaceous material is added. The carbon combines with a certain part of the lime already present to form calcium carbide ($CaC_2$); when cooled the slag turns to a pale gray powder; under certain conditions, when slaked with water, the familiar smell of impure acetylene is noticed, indicating the presence of calcium carbide. A typical analysis of such slag, made in the production of carbon



*Auxiliary Electrical Equipment Has Been Improved Vastly With Passing Years. Photographs show the 4000-kva. transformer and the three electrode lifting motors and counterweights (right), oil switches for control of furnace voltages, and main control panels and part of reaction coils at the left*

toolsteel, is as follows: 0.40% C, 0.35% MnO, 13.5% $SiO_2$, 1.4% $Al_2O_3$, 61.0% CaO, 2.3% MgO, 0.75% FeO, 14.0% $CaF_2$, 5.0% $CaC_2$, and 1.3% CaS.

In the production of low carbon, high alloy steels such as the various grades of stainless, it is necessary to use other reducing agents than carbon. It is customary in making up the reducing slag to use pulverized ferrosilicon, silicon-zirconium, calcium-silicide, manganese-silicon, and shot aluminum.

When the reducing slag is first made up it is dark in color, as it is contaminated with metallic oxides that have worked out of the bath as well as with oxides formed on top of the bath during the slagging operation. As the oxides are reduced by successive additions of reducing agents to the slag the metallic elements such as iron, manganese, tungsten, chromium and vanadium, return to the bath. The progress of deoxidation can readily be followed by observing the surface of the slag, by fracturing samples of the slag, and by examining the solidification of a sample of the metal. As the oxides in the slag are reduced and the oxides in the metal are removed by contact with the reducing slag, the slag will vary in color, black, brown, green, light gray and white. The colors obtained during this transition period depend on the alloys that have been added to the charge.

**Metal and Slag Tests for Stainless Iron**

| Metal | | | Slag | | |
|---|---|---|---|---|---|
| Element | Test No. 1 | Test No. 2 | Compound | Oxidizing (Test No. 1) | Reducing (Test No. 2) |
| C | 0.04 | 0.09 | C | None | 0.04 |
| Mn | 0.05 | 0.51 | MnO | 5.84 | 0.63 |
| P | 0.010 | 0.013 | $P_2O_5$ | 0.30 | 0.03 |
| S | 0.025 | 0.022 | $SO_2$ | 0.21 | 0.50 |
| Si | 0.05 | 0.26 | $SiO_2$ | 14.10 | 27.41 |
| Ni | 0.19 | 0.50 | | | |
| Cr | 0.04 | 12.84 | $Cr_2O_3$ | 0.86 | 0.35 |
| Mo | None | 0.41 | | | |
| | | | $Al_2O_3$ | 3.20 | 5.19 |
| | | | CaO | 20.51 | 46.39 |
| | | | MgO | 11.42 | 15.40 |
| | | | FeO | 41.96 | 1.00 |
| | | | $CaF_2$ | 1.60 | 3.06 |
| | | | Color | Black | White |
| | | | Nature | Stable | Disintegrating |

Alloys to meet the chemical specification are added to the bath during this period. When deoxidation is complete the slag is pale gray or white in appearance and disintegrates rapidly. The temperature of the bath is then regulated until the proper tapping conditions are attained.

This rather cursory statement of toolsteel practice, using the basic lined, arc furnace as the melting and refining medium, indicates that the arc furnace is capable of desirable metallurgical operations which are possible in the fuel-fired open-hearth furnace only with difficulty. Its obvious advantage over the crucible process, as described in Metal Progress last December (page 773), is in the ability to refine a charge, rather than just melt it. A subsequent article will consider the latest melting equipment for special alloy steels, namely, the coreless induction furnace.

# New Copper-Silicon Alloys

## history and foundry practice

An interesting post-War development has been the commercialization of copper-silicon alloys, usually with a little of a third element, by the country's leading brass mills, each under its own trade name. In the cast form they are the equivalent in most respects of the more expensive tin bronzes and gun metal. A second article will deal with their properties and uses in the form of plates, sheet and bars

EVER SINCE HIGH GRADE SILICON METAL OR SILICON-copper alloy has been readily available, it has been used quite widely as a "flux" for copper and its alloys — that is, to promote soundness in ingot or casting. Even before that time, as early as 1883, a "bronze" containing 0.93% silicon was investigated by E. Van der Ven, and in 1885 "silicon bronzes" were being made into telegraph wire by Lazare Weiller in France. As described in "Traité Général des Lignes et Transmission Electriques" by Weiller and Vivarez, the process patented by Weiller in Germany in 1882 consisted of melting the copper under potassium fluo-silicate flux and stirring in a little metallic sodium to reduce the silicon; the resulting metal contained little, if any, residual silicon.

Bridgeport Brass Co. in the 1890's made a bronze wire called "Phono-Electric" containing nominally 98¾% copper and 1¼% tin, fluxed with a 15% silicon-copper "hardener." Although there was so little residual silicon in it, it then had as good a right to be called a "silicon bronze" as a copper alloy similarly treated with phosphorus to be called a "phosphor bronze."

It was anticipated that this material would be useful for telephone circuits (hence the name) but as a matter of fact, it achieved success as trolley wire for heavy traffic street railways, where it was three times as durable as hard drawn copper wire, and the originators monopolized this small market. An even stronger wire (at corresponding expense of conductivity) containing 2% tin was also made for telephone "drop wires," the short lengths leading from poles to house connections.

In 1921 the New Haven railway asked Bridgeport Brass Co. if it could furnish a bronze messenger cable to replace the steel cable then in use on its electrified divisions, but badly corroded by the sulphur-bearing smoke and cinders from locomotives operating on the same tracks. For this purpose electrical conductivity was not so necessary as high strength and corrosion resistance. It was quickly found that 1% silicon added to the drop-wire composition gave an alloy that could be hot rolled into rods and then drawn to over 100,000 psi., still retaining ample ductility for a bend around its own diameter. This alloy of 97% copper, 2% tin and 1% silicon, known as "Phono Hi-Strength," served as messenger cables on practically all the railway electrification projects prior to the depression. A historical note is that the engineering firm of Gibbs and Hill was the first to apply it in the electrification of the Virginian Railway.

The first important application of this copper-tin-silicon alloy in other industries was for cap screws to hold ends on evaporator shells

**By Ernest E. Thum**
Editor, Metal Progress

for Frigidaire units, where a corrosion resistant fastener must be strong enough to compress a lead gasket on the mating surfaces. The wire, cold drawn to 90,000 or 100,000 psi., still had enough residual ductility to be cold headed and roll threaded, and for this use the alloy was called "Duronze," that is, a durable bronze.

Other Duronzes were later formulated and marketed. For instance, the above ternary alloy, Duronze I, was not so good in the form of hot headed ¾-in. bolts, because the strength derived from cold working was lost in the reheating operation. Consequently "Duronze II," a binary alloy, 97% copper, 3% silicon, stronger when annealed, was promoted. (Still later "Duronze III," 91% copper, 7% aluminum, 2% silicon, was the byproduct of a search for a light weight, conductive alloy for suspended electrical constructions.)

### Ternary Copper-Silicon Alloys

So much for the commercial history of an alloy that can fairly be called a binary copper-silicon alloy. Most of the present "silicon bronzes" contain a third element. Notes on this development will now be given.

During the War a search was undertaken by Charles B. Jacobs on behalf of the Du Pont chemical interests for a strong copper alloy of superior resistance to hydrochloric acid at various concentrations and temperatures. It should preferably have little or no tin, since shortage in that metal was embarrassing American industry. Silicon was a logical element to try for at least three reasons: *(a)* Low percentages of silicon form a homogeneous solid solution with copper, much stronger than the pure metal; *(b)* high silicon cast irons were known to be strongly acid resistant; *(c)* unlimited amounts of silicon are available at a moderate price. In the first respect (strengthening by solid solution effect) silicon is similar to zinc, tin, aluminum and nickel, but is about three times as potent as tin, as is roughly indicated in the above tabulation.

Mr. Jacobs was primarily interested in the casting and machining properties of the alloy rather than in its hot working properties. He found that when the silicon much exceeded 3%, the alloys became so hard that they were rather difficult to manage; likewise that if these high alloys were dead melted and cast into a sound ingot or shape they would solidify with quite a coarse grain and be brittle when cold. Ductility he found to be improved by the addition of a third element (preferably manganese, another deoxidizer) and a patent along these lines was issued to him.

The alloy, composed approximately of 96% copper, 3% silicon, 1% manganese, proved itself very useful in many applications in the plants of its original sponsors, having a desirable combination of strength, corrosion resistance, workability and over-all economy. Corrosion resistance is, in general, equivalent to that of pure copper, as it is also approximately equal in thermal expansion, specific heat and specific gravity. The material therefore was readily adaptable to many old applications.

The Du Pont company, although equipped to produce its own requirements in copper alloys, was in no position to exploit this improved material, so the underlying patents were sold to American Brass Co., whose officials were much impressed with its ability to compete with stainless steel, so vigorously being promoted for its strength and corrosion resistance.

In former years *copper* was ordinarily thought of when superior corrosion resistance was sought. Stainless steel not only has that, but great tensile strength as well. Copper-silicon alloys are the first copper alloys of comparable physical properties. It has excellent welding characteristics, so necessary for modern fabrication. Commercially, therefore, it has been a success, because it has put much copper

**Properties of Cast and Annealed Test Pieces** — E. Voce

| | Ultimate Strength | Elongation in 2 In. | Reduction of Area | Brinell Hardness |
|---|---|---|---|---|
| Silicon-copper castings | | | | |
| 3.0 % Si | 33,000 | 36 | 47 | 66 |
| 4.6 % Si | 36,500 | 16 | 17 | 95 |
| 6.5 % Si (as cast) | 32,000 | 0 | 1 | .. |
| Gun metal | | | | |
| 10% Sn, 4% Zn | 38,500 | 26 | 25 | .. |
| Phosphor bronze (as cast) | | | | |
| 12.5% Sn, 1% Zn, 0.24% P | 34,500 | 7 | 8 | 83 |
| Aluminum bronze | | | | |
| 10% Al (not annealed) | 64,000 | 18 | 28 | 112 |

into new applications not open to the older brasses and bronzes, and enabled the copper industry to compete with some of the valuable iron alloys recently discovered. By 1930 the early troubles in mass production had been surmounted and commercial promotion had been so successful that rival mills pricked up interest and two or three variants were introduced by them.

Revere Copper and Brass added 0.5% tin to a 3% silicon-copper alloy for its "Herculoy 418," and Chase Brass and Copper Co. added 1% zinc instead, to form "Type A Olympic Bronze." Phelps Dodge Copper Products Corp. acquired rights under British patents issued to Vickers-Armstrong for "P.M.G. Alloy," wherein by proper proportion of hardener, 1.5% iron is added as a third element to 3% Si, 95.5% Cu. American Brass Co. uses the trade name "Everdur" to include the copper-silicon-manganese alloys of the family patented by Jacobs.

Each of these variants is claimed to have special advantages — such as that a little zinc will improve the casting properties or soundness — but it is also probably true that the third element is little more than a "sweetener" to the plain copper-silicon alloy, enabling that special advantage to be secured somewhat more easily than in the binary alloy. In other words, the essential advantages (high strength, toughness, corrosion resistance, weldability) are inherent in the copper-silicon combination, rather than in the third or fourth element in the composition. At any rate, practice has now become so standardized that the American Society for Testing Materials has approved four tentative standards covering various forms of the material as follows:

| | |
|---|---|
| Plates and sheets for pressure vessels | B96-36T |
| Sheets for forming | B97-36T |
| Rods, bars and shapes | B98-36T |
| Wire | B99-37T |

Federal specifications and U. S. Navy specifications are already in existence.

## Foundry Practice

Many of the brass mills sell casting ingots for use in foundries. In these the silicon is usually high — 4% or over. Quickly melted under glass without stirring, there is little loss in alloying elements; a thin but protective silicate film forms almost instantly on skimming. The alloys are quite fluid; correct casting temperature is as low as the casting can be run successfully; it will be about 2000° F. for large castings, 2100° F. for intricate ones, 2200° F. for very light ones.

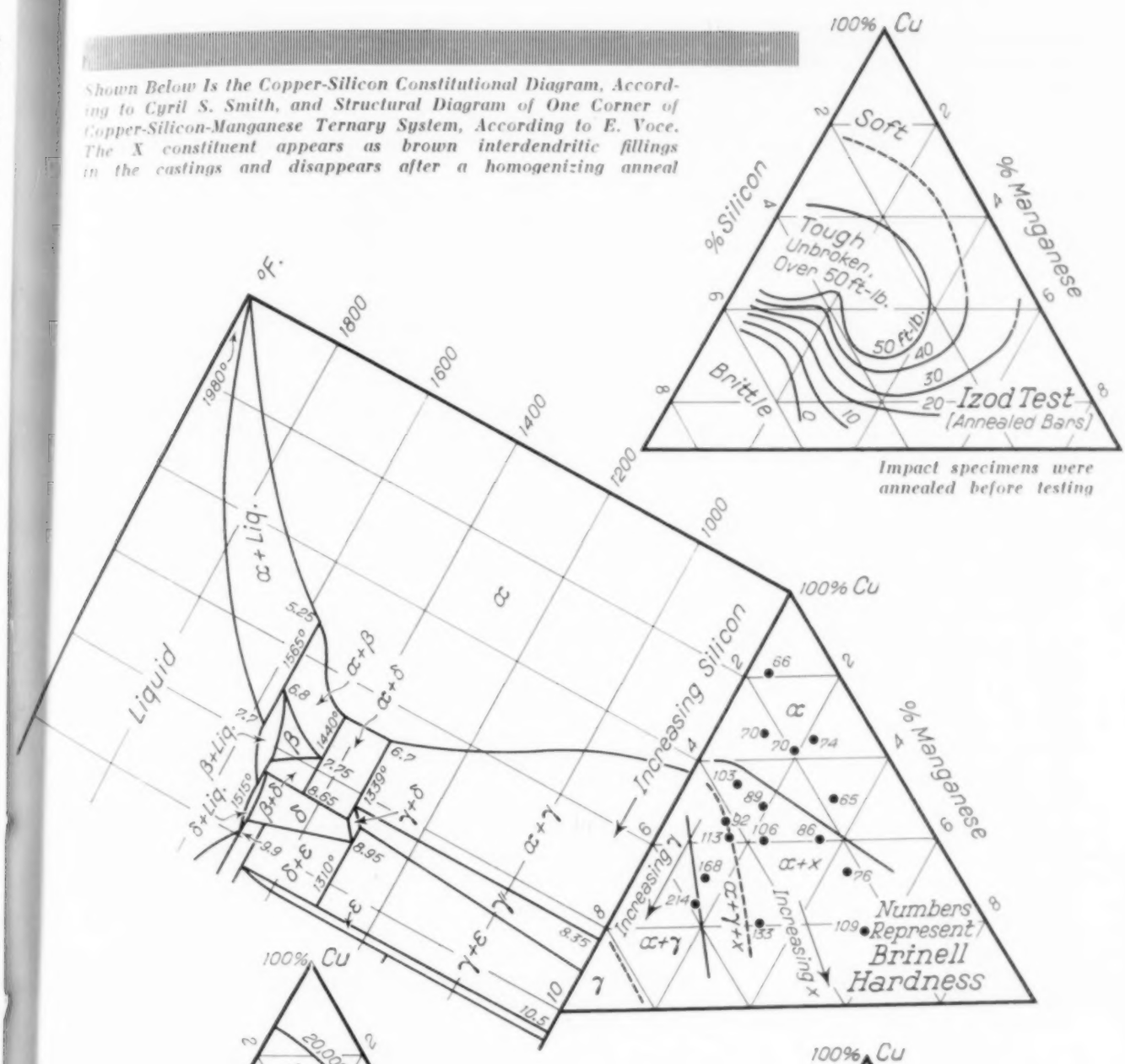
The old-time brass foundryman looks with suspicion on all high strength brasses and bronzes, because most of them have had difficulties with trick alloys in the past. A discussion conference held by the American Foundrymen's Association in Detroit in 1936 indicated, however, that any modern foundry operating under reasonably good control would have little trouble with the "silicon bronzes," especially in dry or permanent molds. They are cheaper in metal cost than tin bronze and easier to handle than aluminum bronze, the two alloys of comparable properties. Minor variations in practice will depend on the nature of the third or fourth alloying element present.

Gas, absorbed during overheating or soaking, especially under partly burned fuel gases, or stirring, is the principal source of foundry trouble, and can be avoided by care in these respects. Molding practice follows that for gun metal, and requires fairly open sand with 5 to 6% moisture, lightly rammed. Baked molds are good for larger castings. Runners should be quite large and placed in the cope to act as feeders during solidification; high sprues and ample reservoirs of molten metal are very necessary to feed castings when they must be pressure tight. The metal has a fairly high contraction in volume as it goes through the mushy range, and porosity or separation at the intercrystalline fillings is a common defect if improperly fed. Gates, basins, strainer gates, by-pass gates and slow pouring — all are useful in avoiding turbulence in the metal while it is filling the mold.

Physical properties of *sound* metal can be measurably improved by annealing at 1300 to 1350° F., although foundries are seldom equipped to do this in a routine manner. This is primarily to homogenize the structure, for in common with all alloys that solidify over a considerable range in temperature, the primary crystals, as cast, show pronounced cores. However, properly made castings, even without annealing, will not show any "chill skin" on a fracture, and a smoothly sawed surface will corrode uniformly when pickled in strong acids. In general, castings are even less susceptible to stress corrosion and penetration than the same composition after rolling into plate or sheet.

Aside from numberless applications in the

*Shown Below Is the Copper-Silicon Constitutional Diagram, According to Cyril S. Smith, and Structural Diagram of One Corner of Copper-Silicon-Manganese Ternary System, According to E. Voce. The X constituent appears as brown interdendritic fillings in the castings and disappears after a homogenizing anneal*




*Impact specimens were annealed before testing*

*Properties of Cast Copper-Silicon-Manganese Alloy, According to E. Voce, are shown in the triangular diagrams*

chemical industry and allied process industries, large uses for cast silicon bronzes have been for cylinder liners, valve bodies and stems, hydraulic fittings, transmission line connectors, and conduit boxes and outlets where hot or corrosive solutions or high pressures must be resisted. Marine hardware, parts for domestic washing machines and garbage disposal devices are other applications. Naval uses are extensive and have warranted the issuance of specification 46B28 by the U. S. Navy and QQ-C-593 by the Federal Specifications Board.

### Copper-Silicon-Manganese Alloys

The principal publication, and one which contains a systematic survey of the copper-silicon and copper-silicon-manganese alloys, is by E. Voce of the British Non-Ferrous Metals Research Association in *Journal* of the Institute of Metals, 1930-II, page 331. From this the diagrams on page 261 are taken.

The binary equilibrium diagram by Cyril S. Smith shows that an alpha solid solution exists up to about 4.0% at room temperature and up to about 700° F., and this solubility increases materially at higher temperatures. The alpha solid solution is a face-centered cubic lattice whose parameter increases slightly with increasing silicon content. The gamma solution is quite complex, containing 20 atoms in the unit cube known as the "beta manganese structure." When annealed metal containing say 5% silicon is slowly cooled the gamma is precipitated in thin plates in the alpha grains. These plates etch bright bluish-white with ferric chloride. Being a quite brittle constituent, its presence is undesirable, despite its strengthening effect.

Mr. Voce's structural diagram shows that a third constituent appears in castings when any sizable amount of manganese is present. For convenience it is called X constituent; it appears between the primary crystals and etches brown with ferric chloride. The X constituent disappears on annealing.

The ternary diagrams show the tensile strength, Brinell hardness and elongation of cast alloys, and the Izod impact values on the annealed specimens. It will be observed that manganese has rather small effect on tensile strength (the contours roughly paralleling the manganese base-line), but that moderate amounts of it improve the ductility of the strongest alloys (3 to 4% silicon) and insure the toughness in annealed castings of a fairly wide range of analyses. These diagrams indicate clearly the logic of Jacobs' original choice—3 to 4% silicon and one-third as much manganese, at least as far as these physical or mechanical properties are concerned.

Mr. Voce found that all the binary silicon-copper alloys up to 5% gave good, machinable castings with tensile properties and hardness similar to the usual tin bronzes and gun metal. Addition of manganese was found to change the corrosion resistance little if any in common acids, mine water and sea water, and in heated air up to 1300° F.

# Cast Iron Gears

By Oliver Smalley

*Abstract from a paper for American Gear Manufacturers Association, 1937*

Cast gears are not necessarily confined to parts where stresses are necessarily low and operating conditions relatively unimportant. In recent years, due to the advancing knowledge of metallurgy and the improvement in the art of foundry practice, cast iron offers for many types of gears properties that not only compare with the so-called superior metals — steel and bronze — but advantageous properties that are peculiar to itself.

Briefly, the progress of all methods of improvement of the so-called modern cast irons may be said to have been concentrated in the control of both the quantity and form of the graphite in a matrix of some predetermined physical constitution. Many methods have been developed to accomplish this, such as: (1) Melting with low total carbon in the electric furnace; (2) addition of special alloys; (3) pouring borderline irons in hot molds; (4) using special methods of casting, followed by a complex heat treatment.

A special form of the second category is a distinctly American development patented by G. F. Meehan about 15 years ago and marketed as "Meehanite." As described in **Metal Progress** for May 1932, "the graphite in this process is controlled by adjusting the chemical composition (principally by melting much steel, if in the cupola) to a point where the castings would normally be white iron, and then causing all (*Continued on page 302*)

# manufacture and use of Powdered Metals

TWO SESSIONS DEVOTED TO POWDER METALLURGY drew the largest audiences at the annual meeting of American Institute of Mining and Metallurgical Engineers in New York last month, and testified to the widespread interest in this new phase of the art. Six papers of descriptive nature were read. These, together with articles by Charles Hardy and Sam L. Hoyt which have appeared in METAL PROGRESS and *Transactions* ⊜, will contain about all the information that has been published of a general nature in American literature. Scientific and technical articles have mostly been confined to the metallurgy of tungsten. It will therefore be a mild surprise to many readers of the new book by W. D. Jones entitled "Principles of Powder Metallurgy" (Longmans, Green and Co., New York) to find so many references to scientific work done on various aspects of this problem in Germany and England.

## Manufacture of Powders

Speaking broadly, powdered metals may be produced in many ways and are utilized for many things besides reconsolidating into sizable metallic objects. D. O. Noel and associates with Metals Disintegrating Co. listed no less than 11 different methods of production:

1. *Machining* — that is, file scruf (which gives the finest particles) or lathe turnings (such as iron for chemical reagent or mixing into hard-finish concretes). Except in the case of expensive dental alloys, this method is too expensive except to make a byproduct.

2. *Milling* or grinding in stamp mills or ball mills (usually preceded by shotting, as below). Brittle metals can be ground easily, although the harder ones may generate so much heat (unless cooled) that they become malleable and "smear." The more malleable metals grind into flakes, and in this way are produced the various powders used for pigments. Malleable metals must be cooled to prevent welding into lumps; this is usually done with a lubricant like stearic acid carried in a solvent. The manufacturing technique is similar to fine grinding of an ore prior to concentration — a continuous flow of the liquid carries out the finest particles which are then separated in classifiers and the coarser portions returned to the mill. The finest sludges are then dried by evaporation, leaving each particle covered with lubricant; the particles are polished in a drum containing internal brushes, and then aged for weeks or months, during which they acquire in some way the property of "floating" on the surface of a paint vehicle and thus drying into a skin of overlapping flakes. Flaky aluminum is also used for curing rubber and for fireworks; flaky copper for commutator and collector rings — to mention some applications other than paint.

3. *Shotting* is done by pouring liquid metal through a screen and allowing the drops to spheroidize by surface tension during free fall into a quenching tank. Lead shot for firearms is made thus, as well as aluminum shot for deoxidizing steel. "Feathered zinc" is made by dropping splatters of liquid zinc into water.

4. *Graining or granulation.* If a metal or alloy is violently stirred while it is solidifying, oxidized particles form — rather coarse in size but sufficient, say, for aluminum in the thermit process, and granulated brass for brazing.

5. *Atomization* — a trickle of metal dropping into a blast of steam or air. An inert gas might be used but it would greatly increase the hazard of spontaneous combustion, for oxide coated particles (about 0.2% oxide by weight) are reasonably safe. The particles themselves have a characteristic shape of ragged tear drops. Particle size is said to be controlled bet-

ter by blowing steam or air under the surface of the molten metal. At any rate, atomized zinc is used for a chemical reducer and for sherardizing, atomized aluminum for fireworks and calorizing, and aluminum plus copper in hot pads for therapeutic purposes.

6. *Condensation* of metal vapor (as the "blue powder," zinc condensed to frost rather than liquid) gives a finer particle size but contains more oxide if secured merely as a cheap byproduct of distillation.

7. *Carbonyl* powders are tiny spheres of onion structure ranging from 1 to 10 microns in size. Iron and nickel are available in this form. If oxides in the form of roasted ore are reduced with hydrogen and then treated in a pressure vessel with CO at slightly elevated temperature, the carbonyl, a compound like $Fe(CO)_5$, comes off as a gas. When pressure and temperature are lowered, usually by diluting with nitrogen, the carbonyl decomposes and the metal comes down as a shower of fine particles, very pure except for their content of carbon and oxygen.

8. *Reduction.* Typical products are the refractory metals like tungsten and tantalum. Chemically purified oxides are heated and reduced to a sponge, usually by hydrogen.

9. *Chemical Precipitation.* The best example is "cement" copper, a sludge precipitated from mine water or dilute leaching solutions by passing it over iron scrap. This is good only for further purification, although fine tin is sometimes made by precipitation on zinc from chloride solution.

10. *Electrodeposition* is utilized to make many metallic powders. Those cell conditions which produce coherent plates are modified to make a spongy deposit, as by increasing the current density and temperature, or by enriching the solution in acid. These powders are light and fluffy crystals after washing carefully and drying in a more or less inert gas.

11. *Distillation* (or dissolution) of a volatile constituent from an amalgam or alloy will leave the more refractory one behind in a very fine sponge, highly reactive, for pyrophoric materials or catalysts.

### Why Do Compacts Cohere?

Methods such as these obviously produce powders of widely different grain sizes, shapes, purity, and surface conditions. A large portion of Dr. Jones's new book, noted at the outset, is concerned with a discussion of how these factors affect the cohesion of a dry-pressed compact and the welding and consolidation during subsequent heat treatment.

Most of the methods of preparation permit an oxidized surface to form on the particles. In fact, as Mr. Noel pointed out, if an oxide-free surface were prepared, it would be destroyed at first exposure to the ambient atmosphere — sometimes, even, with disastrous generation of heat. Dr. Jones believes that the particles can cohere only as rubbing and pressure break through this oxide film, allowing metal-to-metal contact and instantaneous welding at such points. An example of ready weldability of clean metal particles is the gold which dentists tamp into a tooth cavity. Heat treatment of a compact of less noble metal — say iron or copper — should obviously be done in an atmosphere which reduces the oxides on the particles' surfaces. The exact mechanism whereby point contacts (welds) between particles spread into larger areas and the whole porous mass consolidates and shrinks to very low porosity is so obscure that Dr. Jones's discussion of it reads like a series of unanswered questions. Gas, either entrapped in the compact, or occluded on or dissolved in the metal particles, has an important bearing on the ultimate porosity of the heat treated or sintered article, and its shrinkage or warpage from the pressed shape.

These changes in volume during heat treatment, and the phenomenon of "bridging" during pressing which limits the depth of loose powder that can be uniformly compacted under pressure, led one commentator at the A.I.M.E. meeting to state the apparent present limitations of powder metallurgy to rather small articles made in large quantity and not highly accurate in dimensions, thus being analogous to die casting or drop forging in the mass production industries.

This observation was contested by friends of the process. One said that accuracy of 0.002 in. per in. was obtainable by re-pressing after preliminary sintering (but this is not "accurate" to men who are used to splitting thousandths, and involves two extra operations). Another cited the manufacture of a pair of work rolls for a cluster mill, compacted of hard particles, to prove that *size* is not necessarily limited (but two rolls can hardly be called mass production). A third believed that if the particles were made of purest metal they would be soft enough that pressing could be done at

low pressures — on the order of those used for bakelite — and the sizes correspondingly large (but here again crops up the fallacy that *pure* metals are soft or have any other desired superproperty — an idea disproved in this instance by the difficulty of compacting tungsten, chemically prepared to almost spectroscopic purity — and that *pure* metals can be cheap enough to compete with commercially pure ones).

## Classification of Applications

Gregory J. Comstock presented a thoughtful appraisal of the present commercial situation in "Types of Metal Products — a Classification." The oldest and best known reason for using powdered metals is for the preparation of refractory metals like tungsten, tantalum, columbium or molybdenum, unprocurable otherwise. The second unique property cited by Mr. Comstock is also responsible for large-scale operation — the making of a metallurgical concrete, whose aggregate retains its individual characteristics unchanged. This includes *(a)* cutting materials of hard carbides, borides or diamonds cemented with ductile metal like cobalt, and *(b)* electrical contactors of silver, for conductivity, and graphite for lubrication.

Third important class of objects has unique structural effects; this includes *(a)* porous bearings; *(b)* a continuous sponge of high conductivity copper strengthened by hard, unyielding tungsten for spot welder electrodes; *(c)* contact points with flaky copper arranged in parallel layers to conduct current; *(d)* disks having magnetic and non-magnetic components. Another important ability of powder metallurgy is to compound mixtures and, by controlled heating, limit the amount of alloying at the contacting points and thus make articles of two or more metals which transcend the microstructural limitations of melting and casting; this item is especially important in magnetic alloys like iron-nickel-cobalt.

To this classification might be added another item, namely, the addition of a somewhat porous surface to a piece of rolled metal. Instances are clutch disks of steel with a thin layer of copper on the surface, and sprayed coatings from a flame gun using metal powders instead of fusible wire.

Four large-scale present operations (refractory metals, hard carbide tools, porous bearings, and electrical contactors) will, in Mr. Comstock's opinion, be augmented by others where the end result can be achieved more cheaply or more effectively when starting with powders. Of great promise are such methods for handling metals of greatest purity. Likewise he believes that coins can be more cheaply made of powders than from metal strip, if all the costs of rehandling the large amount of scrap in the latter process are included.

## Tantalum and Columbium

A considerable amount of hitherto unpublished data concerning the manufacture of tantalum and columbium was given by C. W. Balke of Fansteel Metallurgical Corp. W. P. Sykes and Philip M. McKenna also augmented the available information respectively on cemented tungsten carbide and tantalum carbide tools.

Tantalum (and columbium) powder is secured from the electrolysis of fluorides; it is coarser in size than tungsten powder from reduced oxide, and contains up to 100 volumes of hydrogen which must be completely eliminated. Particle sizes of each batch of metal are counted, and correct "screen analysis" for compacting secured by mixing selected lots. Owing to the coarse size of the powder and the ductility of the metal, bars weighing 5 to 7 lb. may be compacted in steel dies under pressures of about 50 tons per sq.in. Unless conditions are correct the compacts will have porous centers due to "bridging" or contain "slip cracks" — defects which cannot be corrected later. Even at best there is enough variation in the coherence to cause one side to run hotter than the other when the bar is sintered by electrical resistance, and this variation must not be so pronounced as to affect unduly the homogeneity of the product.

Such sintering is done in a chamber evacuated to a high degree, the evolved hydrogen being continually removed and the heating continued until the vacuum remains steady. The temperature is just below melting at the core (the hottest portion) but this causes no shrinkage. The porous bar is then heated in vacuum and rolled into sheet, which eliminates all porosity observable under a microscope.

Tantalum scrap is handled by converting it into a brittle hydride, grinding it, and reheating in a vacuum. The actual powder is thought by Dr. Balke to approach molecular dimensions; the material, therefore, being sensibly coarse, must be an aggregate at the very start.

# Stress-Rupture Test for heated metal

Design of important equipment operating at high temperatures, like turbines, superheaters and reaction chambers, is based on creep tests. These require too much time for routine acceptance or specification purposes, and the authors propose an alternative which, they believe, will correctly appraise the relative excellence of steels for high temperature service

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IN ALL DISCUSSIONS OF HIGH TEMPERATURE APPLICATIONS it should be recognized that considerable differences may exist in the necessary qualifications. As an example, most applications may be divided into two general groups depending on the permissible amount of deformation during service. In certain applications the total extension is limited to very small amounts of the order of 1.0% in 10 years, while in others relatively large deformations are allowed and, in fact, the life of the equipment is often based on visual extension. Other classifications could be made on the relative importance of strength, corrosion resistance, or structural stability.

Creep characteristics are an ideal basis of design for those applications in which the total amount of deformation is limited to very small amounts. They are likewise of value in the other cases, but do not necessarily define the *complete* behavior of a given steel at high temperature. "Stress-rupture" characteristics are also of considerable value.

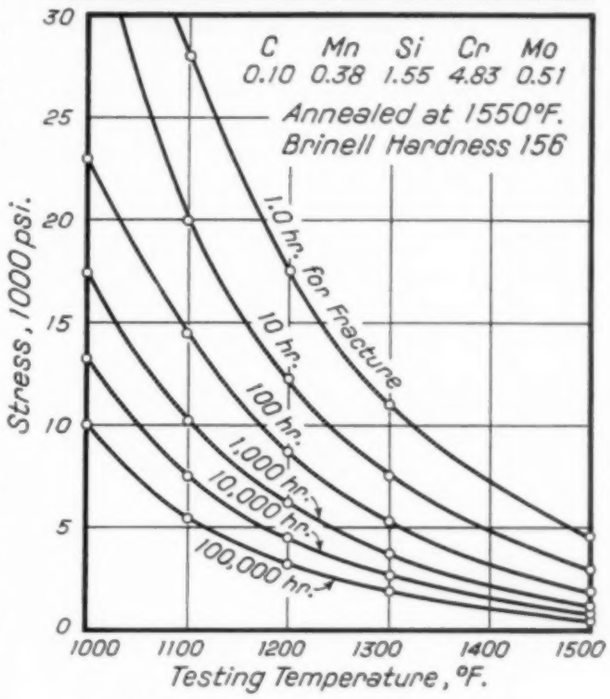
The "stress-rupture" test has already been described in a paper before the last ASTM convention. It consists of making a series of tension specimens, surrounding them with small tube furnaces so they are uniformly at some specified temperature (the regular creep-testing equipment) and adjusting the loads so that fracture occurs in moderate times ranging from a few minutes (short time tensile test, or S.T.T.S. for short) to several thousand hours. It differs from the creep test, however, in that the specimens are carried to actual fracture and the rate of deformation during the test is not necessarily determined. Consequently the stresses employed are greater than those in the average creep test.

All tests to date indicate that the results, plotted on logarithmic paper for a given steel at a given temperature, fall on a single straight-line relationship provided the steel possesses surface and structural stability under the given test conditions. This is shown in the top two lines at the bottom of page 267, and it will be noted that the lines include the short time tensile test, made in 0.1 hr. or 6 min., as well as those requiring about 1500 hr. to

Extracts from a paper for the Western Metal Congress

complete. Under these circumstances it is believed that these lines can be extended a considerable distance to the right, thus giving a close approximation of the results of a stress-rupture test requiring as long as 10,000 hr., or even a considerably longer time.

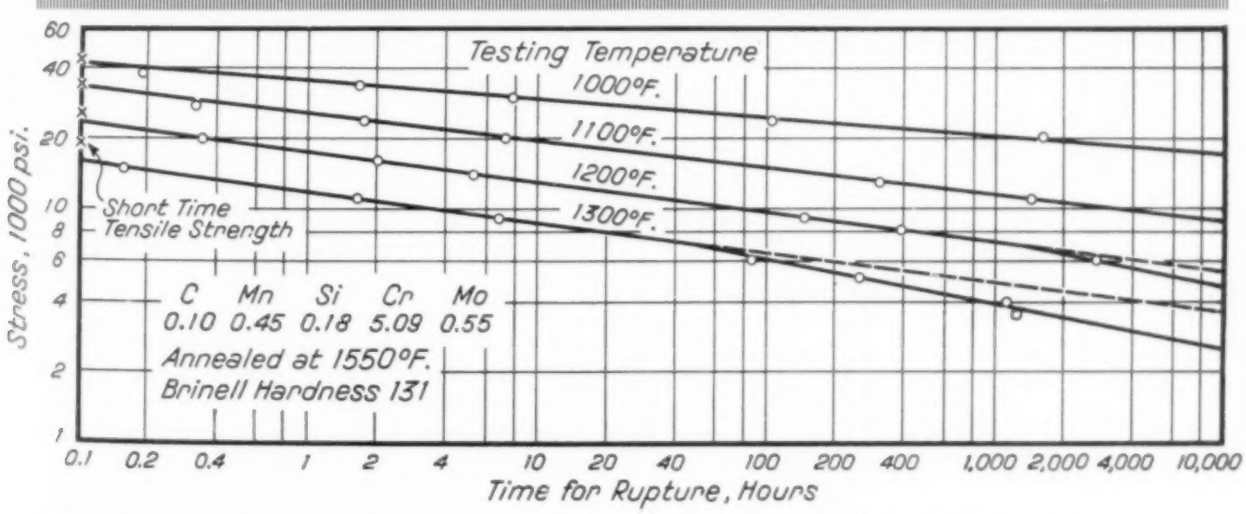
A necessary condition of the above is that the steel be stable under the temperature, atmosphere, and loading imposed. In the absence of sufficient stability, the straight line has a break and the right end drops at a higher slope. However, as shown by the bottom two lines on the same diagram, several tests beyond the break show that it is still straight and can be extended beyond the longest test with some degree of confidence.




*Stress-Rupture Tests Plotted so That Effect of Overheating on Safe Life May Be Determined*

Values of the breaking strength which are so determined should provide information for the design of high temperature equipment in which the amount of permissible deformation is not limited to very small amounts. The factor of safety used must, of course, be greater than when the design is based on creep characteristics and its actual magnitude will depend on the desired life of the equipment, the particular fracture time period used, and the surrounding media to which the metal is to be subjected. The values given in this paper apply to slightly oxidizing conditions.

Stress-rupture tests can likewise be used to indicate the degree of overheating permissible with a particular steel under a given stress. Such a relationship is shown in the figure above. If an operating stress of 5000 lb.




*Time for Fracture Versus Imposed Stress Plots as a Straight Line, Logarithmically, if the Steel Is Stable Under the Temperature and Atmosphere Imposed. More rapid deterioration (instability) is marked by an angle in the line*

is assumed at 1000° F., then for this particular steel the temperature could rise to 1110° F. without fracture resulting in less than 100,000 hr. If the temperature should rise to 1175° F. fracture would occur in 10,000 hr., at 1240° F., in 1000 hr., and at 1400° F. in approximately 10 hr.

Since creep values have been used for design purposes, comparison of the results from the two types of test should give an indication as to the relative factor of safety to be employed. Those given in the adjoining table were obtained under the same slightly oxidizing conditions for identical steels.

A constant relationship evidently does not exist between the creep strength (0.01% per 1000 hr.) and the rupture strength (extrapolated to 100,000 hr.). However, at the temperatures considered, the ratio for all the steels containing from 2.0 to 6.0% chromium is from 0.478 to 0.567. In other words, for pearlitic steels containing medium chromium the stress required for fracture in 100,000 hr. is approximately twice the stress required for a creep rate of 0.01% per 1000 hr. at either 1000, 1100, or 1200° F. It would appear, therefore, that stress-rupture tests can be used for design under certain conditions and with proper correction for the safety factor, if creep values are unknown.

**Stress-Rupture, Creep Strength, and Ratio**

| Steel | Stress for Designated Fracture Time | | | Creep Strength 0.01%/1000 Hr. | Ratio (*b*) |
|---|---|---|---|---|---|
| | 1000 Hr. | 10,000 Hr. | 100,000 Hr. (*a*) | | |
| Testing Temperature: 1000° F. | | | | | |
| 1015(El) | 12,800 | 6,800 | 2,800 | 2,700 | 0.96 |
| 1¼Cr+½Mo+Si | 46,500 | 20,400 | 9,000 | 13,000 | 1.44 |
| 2Cr+½Mo+Si | 19,500 | 15,000 | 11,750 | 5,700 | 0.48 |
| 5Cr+Mo | 20,500 | 17,200 | 14,500 | 7,600 | 0.52 |
| 5Cr+Mo+Si | 17,400 | 13,200 | 10,000 | 5,450 | 0.54 |
| Testing Temperature: 1100° F. | | | | | |
| 2Cr+½Mo+Si | 11,000 | 6,900 | 4,400 | 2,400 | 0.54 |
| 5Cr+Mo | 11,400 | 8,900 | 6,700 | 3,200 | 0.48 |
| 5Cr+Mo+Ti | 9,300 | 5,800 | 3,500 | .... | .... |
| 5Cr+Mo+Si | 10,250 | 7,500 | 5,400 | 2,600 | 0.48 |
| Testing Temperature: 1200° F. | | | | | |
| 1015(El) | 2,500 | 1,220 | 600 | 290 | 0.48 |
| 1¼Cr+Mo+Si | 7,000 | 3,950 | 2,200 | 1,080 | 0.49 |
| 2Cr+Mo+Si | 6,400 | 4,250 | 2,800 | 1,400 | 0.50 |
| 5Cr+Mo | 7,200 | 4,700 | 3,000 | 1,700 | 0.57 |
| 5Cr+Mo+Ti | 5,000 | 3,350 | 2,200 | .... | .... |
| 5Cr+Mo+Si | 6,200 | 4,400 | 3,150 | 1,600 | 0.51 |
| Testing Temperature: 1300° F. | | | | | |
| 1015(El) | 1,400 | 720 | .... | | |
| 1¼Cr+Mo+Si | 2,700 | 1,300 | .... | | |
| 5Cr+Mo | 3,900 | 2,500 | 1,600 | | |
| 5Cr+Mo+Ti | 2,800 | 1,900 | 1,240 | | |
| 5Cr+Mo+Si | 3,700 | 2,650 | 1,850 | | |
| 18-8 | 9,100 | 5,800 | 3,700 | | |
| Testing Temperature: 1500° F. | | | | | |
| 5Cr+Mo+Si | 1,160 | 740 | 470 | | |
| 18-8 | 4,100 | 2,600 | 1,700 | 1,400 | 0.82 |

Notes: (*a*) Extrapolated. (*b*) Creep strength divided by stress-rupture for 100,000 hr.

## Rupture Time Versus Ductility

One of the chief merits of this test is believed to be its ability to show the influence of time, temperature and stress on the resulting ductility in any given atmosphere or medium. This is especially important in those applications in which relatively large deformations are allowable and in which the life of the part is based on a certain visual extension. In other words, in those applications it is of great importance to know if the particular steel will deform this amount, under the given operating conditions, before actual failure results.

The ductility characteristics of many of the fractured specimens are summarized in a table in the A.S.T.M. convention paper last fall. They show the ductility to be independent of the fracture time for certain of the steels at certain temperatures, but for others, the ductility decreases as the time for fracture is extended. In some cases this decrease is not especially pronounced while in others it is. A brief discussion of this important result is in order.

Steel 1015(El) at 1000° F. may be used as an example of a serious decrease in ductility. The short time tensile specimen possessed an elongation value of 42.5% while the corresponding value for the specimen which required 10,000 hr. for fracture was only 12.0%. Furthermore, the trend of the results would indicate a continual decrease in this ductility as the fracture time was further extended. At 1200 and 1300° F. the ductility of this steel also decreases but the changes are of a smaller order of magnitude and the trend of the values would indicate that the ductility would not fall below 20.0%.

Metallographic examination shows that this pronounced decrease in ductility with increasing fracture times is in general a manifestation of either surface or structural instability.

With respect to surface stability two types of attack must be considered. One may be defined as general attack since the entire surface of the

*(Continued on page 298)*

# nitrogen added from Titanium Cyano-Nitride to the chromium irons

Chromium-iron alloys, containing 25% chromium or more, solidify with very coarse grains and are correspondingly brittle. The ferrite in these alloys has no transformation points, consequently the castings or plates cannot be grain refined by heat treatment. Nitrogen causes a finer grained ingot or casting, and titanium cyano-nitride is a good source of this element, giving in addition the element titanium which is an excellent deoxidizer

THE VALUE OF NITROGEN IN HIGH CHROMIUM steels has been known since the publication of Frank Adcock's paper on this subject by the British Iron and Steel Institute in 1926. Its effects have been described in more detail by Russell Franks in *Iron Age* for Sept. 7, 1933, and in *Transactions* ASM, Vol. 23, p. 968, and by J. A. Jones in *The Metallurgist* (supplement to *The Engineer*) for Feb. 28, 1936. It has thus become fairly well known that nitrogen is readily absorbed and retained by high chromium-iron alloys, low in carbon, and that, with a nitrogen content of about 1% of the chromium, the grain size of these ferritic irons and steels is refined, with improved physical properties after long periods of time at high temperature, and without impairment of the resistance to oxidation.

Nitrogen is generally added to these alloys by means of the ferrochromium used in making them, a brand of this ferro with a definitely high nitrogen content being available commercially. Practical experience with this high nitrogen ferrochromium has not always been favorable, however, so that an alternative method for making a desired nitrogen addition to high chromium steels may be of interest.

This method, for which patents have recently been granted and which has been developed in the metallurgical research laboratory of the Titanium Alloy Mfg. Co. consists in the addition of titanium cyano-nitride to the steel while it is being melted. A representative analysis of this compound is about as follows: 80% titanium, 3% carbon, 7% nitrogen, 2% iron, and 0.3% silicon. When this is added with ordinary low carbon ferrochromium to the charge for making steel in the electric furnace, this compound is decomposed, the nitrogen passing into the steel as chromium nitride, and the titanium is liberated to deoxidize the steel, eventually being largely lost as titanium dioxide. Zirconium cyano-nitride has been found to act in a similar way except that, as it is generally lower in nitrogen than the titanium compound and more reactive, more of it must be used for a given nitrogen addition, and the zirconium is always

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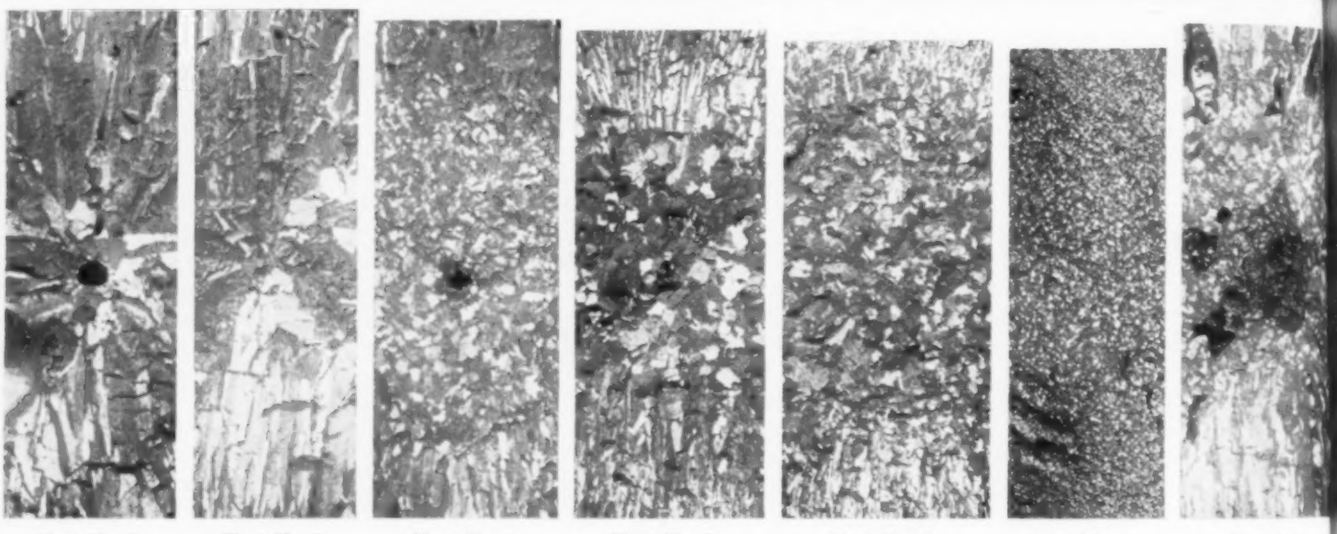
completely absent from the finished steel. This paper will therefore deal chiefly with the titanium compound, since it seems to be of greater practical interest for improving high chromium irons and steels.

Experience in several steel foundries has shown that it is much easier to secure fine-grained, high chromium steel castings that are sound and free from porosity when titanium cyano-nitride is used as the source of nitrogen than when high nitrogen ferrochromium is used. With the former no special attention to temperature or time of holding the heat is required, while with the latter, even with the special precautions regarding superheating, porosity due to the evolution of gas from the solidifying casting is very frequent.

Several methods of adding the titanium cyano-nitride are permissible, all being very simple. To facilitate solution and reaction with the molten metal the compound should be crushed rather fine, a size passing through a 20-mesh screen having been found satisfactory. In making the addition to the steel, it may be mixed with the low nitrogen ferrochromium and both alloys added together to the bath. Or the titanium cyano-nitride may be charged on the molten iron, after removing the slag, and covered immediately with the ferrochromium. Somewhat less desirable methods are *(a)* adding just before the iron scrap is entirely melted or *(b)* stirring the cyano-nitride into the completed melt after the ferrochromium has been dissolved. Care should be taken to see that the cyano-nitride is not lost by mixing with slag, and of course it should not be preheated as ferrochromium sometimes is. The addition should be made in the furnace rather than in the ladle, since the compound is too refractory to mix well with the steel in the short time available in the ladle, and the reaction involving the liberation of nitrogen also requires a little time. For best recovery of nitrogen the presence of some slag which will readily absorb titanium dioxide is desirable; in induction furnace melting, where there may be very little slag on the melt, the addition of a small amount of lime is therefore helpful.



Heat No. 2 Untreated | Heat No. 3 1.1% TiCN | Heat No. 4 1.8% TiCN | Heat No. 6 2.2% TiCN | Heat No. 7 3.8% TiCN | Heat No. 8 3.3% ZrCN | Heat No. 9 High N Fe

*Test Ingots of 24% Chromium Irons, Broken Near Top End, Slightly Reduced in Reproduction, Showing How Primary Crystallization Is Modified By Nitrogen, Titanium and Zirconium*

To illustrate the results obtainable by this practice, some tests of 24% chromium-iron alloys made in the laboratory will be described. Ten heats were melted from Armco iron scrap and low carbon ferrochromium in magnesia crucibles in a 17-lb. Ajax-Northrup high frequency induction furnace, and each heat was poured into a single ingot mold with a refrac-

tory hot top. After pouring, the sink head was filled with "Bruenella anti-piping powder." The charge for these heats consisted of about 61 to 63% Armco iron and 35 to 36% ferrochromium containing 66% chromium and less than 0.1% carbon. For deoxidation about 0.3% ferromanganese (low carbon) and 0.5% of 50% ferrosilicon were used in each heat.

Two of the heats, No. 1 and 2, were made without any nitrogen addition as a basis for comparison and two, No. 9 and 10, were made with high nitrogen ferrochromium replacing about half the regular ferrochromium addition. (This high nitrogen ferro was reported to contain 71.2% Cr, 0.06% C, and 0.7% N. The other ferrochromium was found to contain 0.11% N.) Five heats, No. 3 to 7, were made with nitrogen added in the form of titanium cyano-nitride, the amounts of this compound added being from 1.1 to 3.8%; and one heat, No. 8, was made with an addition of 3.3% zirconium cyano-nitride. Alternative practices within the useful range could then be compared.

**Analysis of the Melts**

| Heat No. | Source of Nitrogen | Analysis | |
|---|---|---|---|
| | | N | C |
| 1 | None | 0.081 | 0.12 |
| 2 | None | 0.156 | 0.05 |
| 3 | 1.1% TiCN | 0.155 | 0.08 |
| 4 | 1.8% TiCN | 0.182 | 0.07 |
| 5 | 1.9% TiCN | 0.258 | 0.20 |
| 6 | 2.2% TiCN | 0.240 | 0.09 |
| 7 | 3.8% TiCN | 0.234 | 0.17 |
| 8 | 3.3% ZrCN | 0.207 | 0.02 |
| 9 | 20% High N FeCr | 0.298 | 0.01 |
| 10 | 17% High N FeCr | 0.272 | 0.15 |

The melting practice followed by my associate V. V. Efimoff was to melt down the iron scrap in about 25 to 35 min., then add the ferromanganese, half the ferrosilicon, a little lime, and the first of the ferrochromium mixed with the nitrogen-bearing alloy. This addition was generally completed in 15 to 25 min., depending on how rapidly the induction furnace would heat at the time when the experiment was made. The alloy was then brought up to pouring temperature in about 15 to 20 min. more, the rest of the ferrosilicon was added, and the ingot was poured 3 to 5 min. later. The pouring temperature was controlled by sighting with an optical pyrometer on the top of the melt, the heat being adjusted so as to obtain a reading of 2810° F., and with the usual correction for emissivity this should represent a true temperature of about 3080° F. The metal was poured slowly; considerable trouble was experienced in maintaining the cast iron stools on which the molds were set.

This practice gave ingots containing about 23.5 to 24.5% chromium, about 0.35% silicon, not over 0.20% carbon, 0.012 to 0.124% titanium, and 0.081 to 0.298% nitrogen. Analyses are found in the adjoining table. The higher carbon contents were found in Heats No. 1, 5, 7, and 10 in which 1.5% of the charge was high carbon ferrochromium substituted for an equal amount of low carbon ferro. Heats No. 1 and 2, having no nitrogen designedly added, were found to contain 0.012% titanium and 0.081 to 0.156% nitrogen, showing that considerable nitrogen may be absorbed from the air during melting. This makes it rather difficult to control accurately the nitrogen content in a high chromium alloy melted in small induction furnace heats, and also to compute nitrogen recoveries from the cyano-nitride additions. Assuming a 0.13% nitrogen pickup from extraneous sources, the recovery of nitrogen from the titanium cyano-nitride in these heats varied from 31% in Heat No.

*Reference Series of Fractures of Tensile Bars Ranged in Order of Fineness of Grain*

3 to 93% in Heat No. 5, (40% to 71% in the others); recovery from the zirconium cyanonitride (containing about 2.5% nitrogen) in heat No. 8 was about 90%. Figuring the two heats, No. 9 and 10, made with high nitrogen ferrochromium on the same basis the results come to 138 to 144%, indicating that the nitrogen content of this alloy must have been higher than reported by the manufacturer. Titanium recoveries were only 2.5 to 4.5%, and the zirconium recovery was nil.

The ingots made in this way were cropped by nicking and breaking about ½ in. below the hot top. The fracture was photographed so that the grain sizes and soundness may be compared. The top discards amounted to about 15 to 23%, but the pipe was not always entirely removed. (See cut on page 270.)

The cropped ingots were heated slowly and carefully and forged under an air hammer to about ⅞-in. rounds or ¾-in. squares. Bars were then cut into 6-in. lengths, using the lower central parts of the ingots as much as possible, and these short samples were heat treated and subsequently machined into tensile test specimens ½ in. diameter between shoulders 2 in. apart. One bar from each ingot, however, was tested as forged, without any heat treatment. The heat treatments which were applied to the others were as follows:

A — None; tested as forged.
B — Annealed at 1650° F. 3 hr., cooled in furnace.
C — Normalized, 1750° F. 1 hr., cooled in air.
D — Heated at 1950° F. 5 hr., cooled in air.
E — Heated at 2150° F. 12 hr., cooled in air.

Heat treatment E was performed in the forging furnace, controlled manually with the aid of an optical pyrometer. The others were carried out in an automatically controlled electric muffle.

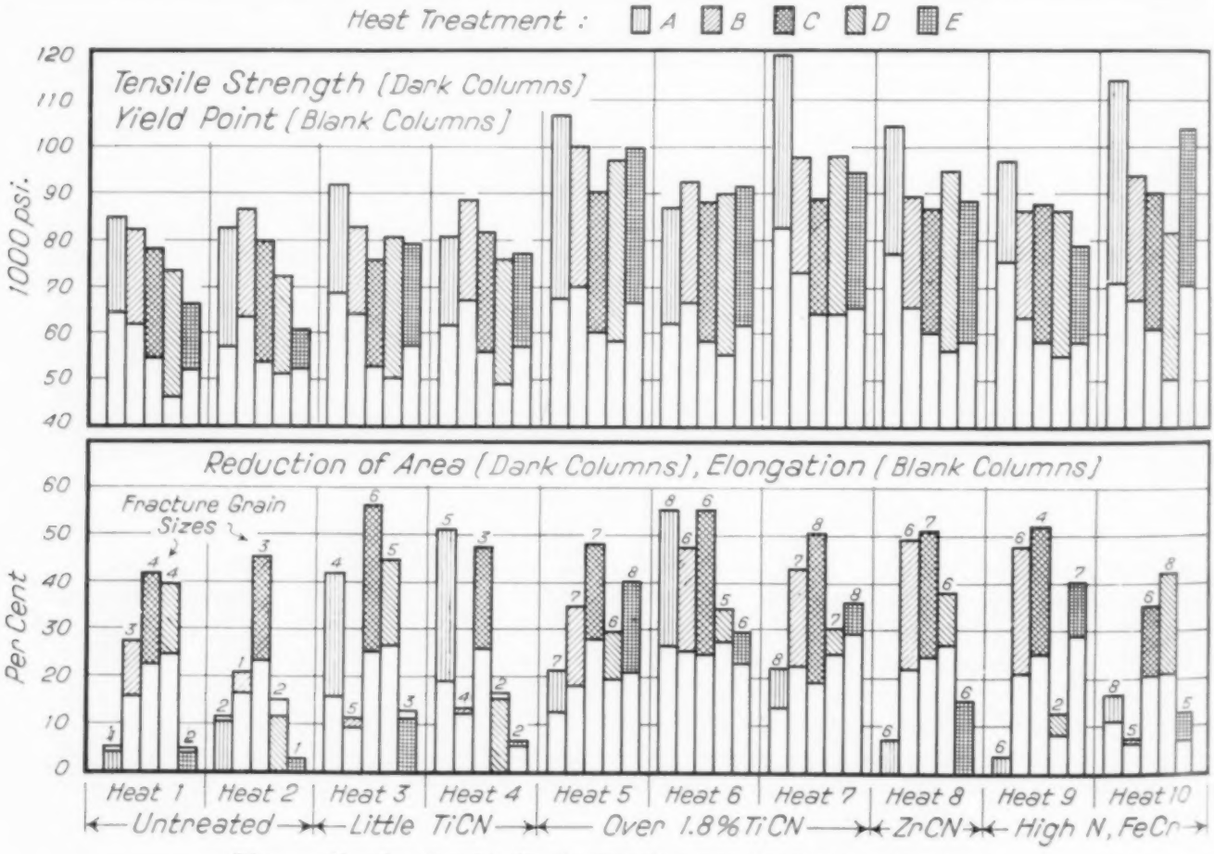
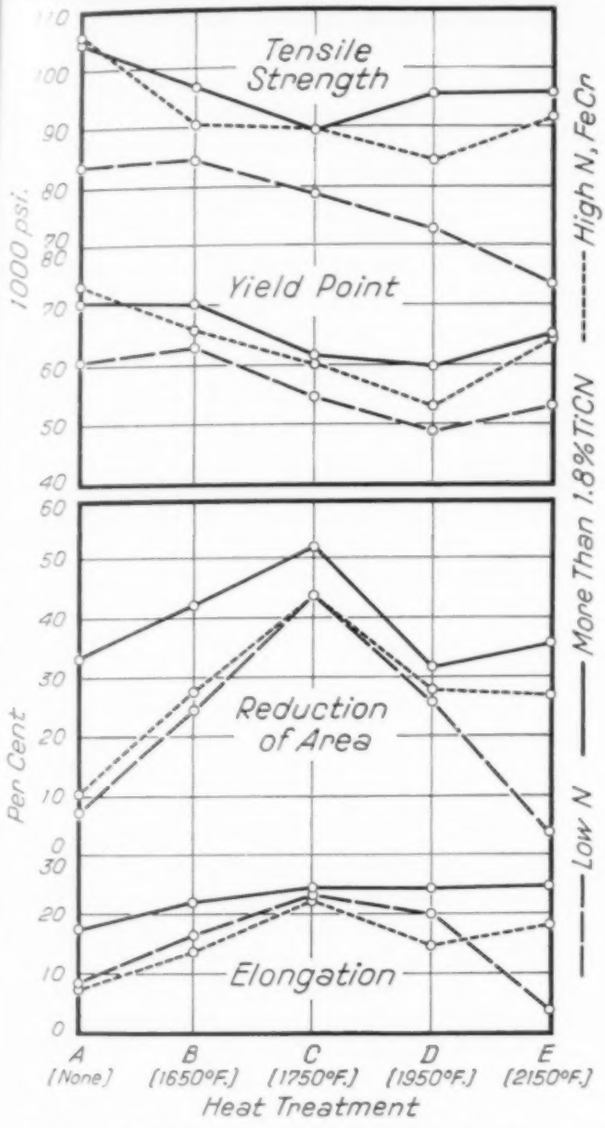



*Diagram Showing Graphically the Tensile Properties of 24% Chromium Irons, as Affected by Method of Adding Nitrogen and by Heat Treatment*




*Summary of Effect of Higher Temperature and Longer Time on the Tensile Properties of Three Classes of Heats. Dotted lines are averages for Heats No. 1 and 2, with no nitrogen intentionally added; full lines are averages for No. 5, 6 and 7, with more than 1.8% TiCN; dashed lines are heats made with high nitrogen ferrochrome*

Tension tests were made at slow speed and room temperature, the yield point being taken as the stress producing an extension of 0.5% as measured under load with a strain gage. Rockwell B hardness was determined on one end where the grips of the testing machine had not been in contact. Variations in hardness were not very significant; the forged bars were B-86 to B-96 (roughly paralleling the tensile strength). Heat treatment C, which gave the most ductile bars, also produced the most uniform hardness, the range for the ten heats being B-82 to B-89. Higher and longer soakings tended to soften the alloys slightly, the range for heat treatment E being B-79 to B-90.

In looking over the results it is apparent that the samples treated with over 1.8% TiCN and containing over 0.2% nitrogen from this source had uniformly fine fractures and good strength and ductility after all heat treatments, while the results from the other steels were irregular. Normalizing benefits all of them, but the other and longer heat treatments were especially designed to bring out the bad effects of a coarse grain size.

The results can perhaps be appreciated better from the diagrams. In the first figure are plotted all the tensile test data. (The as-forged steels depend to some extent on the finishing temperature of forging as well as on the character of the alloy.) It shows rather clearly that *all* the values for Heats No. 5, 6, and 7, treated with over 1.8% TiCN, are comparatively high, while many of the values for all the others are quite low, indicating poor physical properties after some of the heat treatments. The vertical bars for ductility after long soaking at high temperature (heat treatment E) are particularly interesting, and bring out strikingly the advantages of the treatment with titanium cyanonitride. High nitrogen ferrochromium gave irregular results, showing that a nitrogen content alone was not sufficient to insure a fine grain and good tensile properties. Some of the irregularities in the results from Heats No. 9 and 10 may have been due to unsoundness of the ingots, although they seemed to forge all right, and the heat treated bars were not defective.

The data are plotted in a simpler way on the second diagram. Heats No. 3 and 4, treated with insufficient TiCN, and Heat No. 8 with ZrCN were omitted from this chart, and the others were grouped into three classes, each curve being plotted from average values for its particular class. In this way the consistent superiority of the alloys when properly treated with TiCN is very clearly brought out, with the steel made from high nitrogen ferrochromium occupying generally an intermediate position. (It may be noted that in this figure the temperature of heat treatment increases from left to right, although not regularly.)

It was interesting to note from the fractures that the grain size of the ingot is not an infallible

guide to the grain size and properties of the steel after forging and heat treatment. Although in general the coarser-grained ingots gave bars with poorer properties than those that were finer-grained, there were notable exceptions. Ingot No. 8, for instance, was the finest-grained of all, yet the heat treated bars from it were by no means the best; likewise some of the bars from Heat No. 10 showed good properties, although its ingot fracture was coarse. These discrepancies may be due to variations in temperature of the steel when poured that were not disclosed by optical pyrometer readings taken at the top of the melt.

These excellent results with titanium cyano-nitride in high chromium irons and steels have been checked in actual practice at several foundries where trouble had been experienced with the soundness of castings. In these tests the titanium compound when added effectively always gave sound castings as well as fine-grained steel. The most effective way of using it, both in arc and induction furnace practice, was to add it to the bare steel either just before the ferrochromium so that the latter covered the TiCN at once, or mixed with the ferrochromium, but without preheating. The amount needed for 25% chromium-iron alloys seems to be about 1.5 to 2%. Probably in larger scale practice somewhat less than the 1.9% addition required in our 17-lb. melts would be sufficient; in lower chromium steel, also, less would be needed.

Of course it is not by any means claimed that good results are not possible with correct practice with high nitrogen ferrochromium. Our experience, however, in foundries as well as in the laboratory, indicates fairly definitely that soundness and successful grain refinement are much more readily attained together when TiCN is used as the source of nitrogen.

The reason for this advantage is undoubtedly the availability of titanium, derived from the cyano-nitride addition, for deoxidation and scavenging. Since the recovery of nitrogen from this addition was 31 to 93%, while not over 5% of the titanium was retained, it is evident that nitrogen must have been given up by the titanium to the chromium. The titanium in this addition then served to improve the soundness and cleanness of the steel, passing into the slag in the usual way as $TiO_2$. This action is readily explained on theoretical grounds from the greater stability of $TiO_2$ as compared to TiCN under steel-making conditions.

# Allotropy of Stainless Steels

Frederick M. Becket, in the Howe Memorial Lecture, views such practical matters as weld decay, mixed structures, 475° brittleness, and grain size, from the scientific aspect of allotropic changes in the iron

INTERGRANULAR CORROSION OF THE 18% NICKEL, 8% chromium stainless steel was the first topic discussed by Frederick M. Becket in his Howe Memorial Lecture, delivered last month before the American Institute of Mining and Metallurgical Engineers in New York City. He pointed out that early failures of this corrosion resistant alloy, temporarily rendered corrodible by improper heat treatment, were matters of history, and the technique of steel manufacture and fabrication should now be well enough known to render any similar trouble inexcusable. He was not so sure, however, that the widest accepted theory as to the cause is exactly correct. It may be recalled that mild heating to an intermediate temperature range is supposed to cause precipitation of carbides at the grain boundaries in this austenitic alloy, and these carbides, being richer in chromium than the average of the metal, correspondingly deplete the alloy in their vicinity to a point where it no longer contains enough chromium to be corrosion resistant.

Dr. Becket would rather ascribe this induced corrodibility to the internal mechanical strain associated with the allotropic change in iron, alpha iron having a lower density than the gamma from which it was formed. Granted that 18-8 steel, properly made, is an aggregation of metastable austenitic crystals at room

temperature, mild heating to say 600° C. (1100° F.) will cause some of this gamma solid solution to transform allotropically into alpha solid solution with simultaneous precipitation of ultra-microscopic carbides. It is unnecessary to assume that these carbides are high in chromium, for the reaction naturally starts at grain boundaries, and is analogous to the formation of "nodular troostite" in carbon steels — a metallographic constituent that is most corrodible of all the transition products of hardening and tempering. This corrodibility is, in the lecturer's opinion, due to the internal mechanical strain caused by volume differences between the two space lattices, and he also believes that this internal strain is strong enough to cause intercrystalline corrosion in 18-8 and alloys of mixed austenitic and ferritic structure.

The above course of reasoning justified a consideration of intercrystalline corrosion in a lecture "On the Allotropy of Stainless Steels." Pursuing the matter further, Dr. Becket considered the mixed structures — those normally containing both austenite and ferrite — structures that in the past have been avoided by steel makers. It has been customary, for instance, to increase the nickel and add manganese up to 2% (both elements promoting the austenitic phase) in 18-8's containing much molybdenum or other ferrite-forming elements.

Ferrite, as such, in mixed structures should not be universally condemned, for it would appear that a little ferrite causes a strained and corrodible structure, whereas an analysis that produces considerable ferrite in austenite is quite corrosion resistant. For instance, if the 8% nickel in an 18-8 is entirely replaced by manganese (carbon remaining as low as 0.10%), the microstructure contains 40% ferrite and the metal may be easily rolled hot. This is likewise true if the sum of nickel and manganese in a low carbon 18% chromium alloy is above 10%. For instance, the 18% chromium alloy containing 4% nickel and 6% manganese has about 20% ferrite and 80% austenite in its normal structure. Changing the analysis to 18% Cr, 6% Ni and 4% Mn, there appears only 5% ferrite, but this is apparently enough to avoid high localized internal stresses due to allotropic changes and the metal is an excellent resistor of industrial atmospheres. It is now produced commercially.

A simplified view of the iron-chromium system would show the alloys to be alpha (or delta) solid solutions when the chromium exceeds perhaps 15%. Close students have suspected that it is not as simple as this, for under certain circumstances the alpha solution (body-centered cubic lattice) produces spontaneously a very hard and brittle substance. This appears in low carbon alloys like 29 Cr, 10 Ni, and in the iron-chromium-silicon alloys containing 15% chromium and higher. It has been variously termed the "B-constituent," or the "sigma phase," or an intermetallic compound FeCr. Dr. Becket is inclined to the view that it is an allotropic phase; among other evidence is the fact that dilatometric studies show its appearance to be associated with an unmistakable contraction in volume.

Some investigators ascribe the so-called "475° brittleness" to this sigma phase, but the lecturer assembled facts to uphold his view that this effect was rather caused by some other submicroscopic precipitate of unknown composition. Some facts concerning its occurrence are as follows: If a 25% chromium-iron containing 0.10% carbon is heated within the range 400 to 490° C. (750 to 900° F.) and slowly cooled, it will be brittle if tested in bending at room temperature. However, the metal is not brittle if tested at 475° C., nor is it brittle at room temperature after rapid cooling from 475. Also an embrittled sample may be toughened by reheating above 500° C. [These circumstances may recall the "temper brittleness" of low chromium and chromium-nickel steels.]

It appears that at least 20% chromium is needed in the iron-chromium alloy for this phenomenon to occur. This corresponds to the limit where the second major increase in corrosion occurs. However, this does not seem to be valid reason for the assumption of a "super-structure" of iron-chromium to explain the brittleness. It is doubtful if carbon is an essential factor, for "carbon-free" alloys made from electrolytic metal show 475° brittleness, as do others containing 21 to 35% Cr and carbon as low as 0.006%. The only non-susceptible piece of such metal Dr. Becket and his associates in Carbide and Carbon Research Laboratories found was some strip, vacuum annealed.

In concluding, the lecturer called attention to the action of nitrogen in high chromium-iron alloys, remarking that it is more powerful than carbon in promoting and stabilizing austenite. Like other "stranger" elements in small percentages, nitrogen accelerates the formation of sigma phase in susceptible alloys.

*While Some of the Views in This Assemblage Are Out of Scale, it Will Indicate the Range of Shape, Size and Complexity of Pieces Now Cast in Heat Resisting Alloy. Courtesy General Alloys Co.*

# Damage to Muffles

## by controlled atmospheres

Carbonaceous gases, especially those prepared for carburizing of steel, react with nickel-chromium-iron alloys to their detriment. Discussion of this problem tends to emphasize the relatively infrequent failures and distorts the true picture, which is actually one of great and increasing satisfaction with these heat resisting castings

NEWER PRACTICES IN GAS CARBURIZING AND HEAT treatment in controlled atmospheres are causing some trouble with the muffles, resistors, thermocouples and other parts made of heat resisting alloys. While this is in most instances confined to gas carburizing furnaces with horizontal muffles, and at the charging end where temperature differentials are greatest, exposure to hot reducing and carburizing gases should really be expected to cause some trouble with alloys intended primarily to resist hot *oxidizing* conditions. The penetration of reducing and carburizing gases through the oxidized coating that is the real protective skin seems to be the cause, for instance, of the rapid deterioration of thermocouple wires, even when enclosed in protection tubes. This is such a quick action that substantial variation from correct indications has been noted in a single day's operation in a gas carburizer.

Users of important quantities of nickel-chromium alloys for heat resistance, in a discussion conference recently held by the Cleveland Chapter ⊜ and led by Harrison I. Dixon, did not seem to be much concerned over the endurance of present-day alloys to ordinary furnace atmospheres (hot flue gases from fuel combustion) or in service as carburizing boxes. There are plenty of the latter, ten years old and still going strong. A notable improvement in serviceability in more severe conditions, estimated as at least 50% by one user who disclaimed being an enthusiast, has been achieved in the last two or three years by closer attention in the foundry to raw materials and analysis, melting and deoxidation practice, pouring temperatures, molding methods, sand control and X-ray inspection.

In certain classes of work — notably the type of rotating retort where through-put is steady and thermal conditions are uniform — the alloy wears thin rather than fails by cracking or localized disintegration. A minimum of 7500 hr. service would confidently be expected in such cases. It is then doubtless better to pay more money for higher nickel-chromium alloys than to replace less expensive materials more frequently, even though the service requirements may be described as mild rather than severe. Furthermore, in other instances of much more severe service, as when empty boxes are quickly cooled in air, trays or fixtures are quenched, or where a batch type muffle at say 1500 to 1700° F. has half a ton of cold steel placed on its floor, nothing but alloys of the high nickel type will stand up for any reasonable length of time.

However, where uncertainties and variables

in furnace operations are such as to prevent any accurate estimate of the life of cast alloy, it was the concensus of users that the less expensive types would be cheaper in the long run, or at least until operating conditions are under control. Depending on individual circumstances, compositions like 35-15 Ni-Cr, 25-18 Ni-Cr, or 25-12 Cr-Ni are then indicated. This statement, of course, is made without prejudice to the last-mentioned types, which have earned a reputation for reliability in applications such as conveyor parts and corrosion resisting castings.

Likewise, a lot could have been said by producers of castings about the so-called human element, still a big factor in the use and abuse of heat resisting castings, and the reluctance of many customers to change details of their processes so as to give the alloys a better chance to withstand the hot corrosive surroundings. Finally, as one foundryman put it, the alloy business has been acquiring experience for more than 20 years, and while there are still some unknowns in the older usages and more in the new ones, the maker of castings can nearly always give worth-while advice as to the life expectancy of a given alloy in a given design and use. One failure of a low-priced alloy that could have been prevented by a high-priced alloy costs more than the anticipated saving.

Atmospheres of the non-oxidizing type, especially at hardening temperatures, cause many unexpected difficulties. If the tendency is at all carburizing — and most of these are run definitely on the carburizing side to avoid soft skin on the work — the surface layers of retorts and containers will gradually pick up carbon. This has two bad effects on perfectly sound metal — first, the natural loss in toughness of a higher and higher carbon alloy and second, the solid solution crystals are changed in analysis due to the abstraction of carbide-forming elements therefrom. The primary carbides may also change in form and constitution with an increase in volume, leading to internal checks. One user went so far as to say he had predicted trouble from the mechanical action of soot deposited in crevices or discontinuities such as "wash" or mold marks. At any rate, surface irregularities such as the print of a grain of sand from the mold will pack hard with soot or amorphous carbon.

Deterioration is in most instances, however, located at spots such as changes in section where stress concentrations will exist or where casting defects would be suspected. This emphasizes the necessity of careful design and excellent foundry practice. Although there may be no indication of internal cavities or sponginess, the

## Classification of Common Heat Resistant Alloys

H.I.Dixon

| No. | Manufacturer | Trade Name | Designation of Alloy Casting Industry | | | | | 80-20 Alloy |
|---|---|---|---|---|---|---|---|---|
| | | | C-20 | CN-30 | NC-4 | NC-2 | NC-1 | |
| 115 | American Manganese Steel Co. | Amsco | F-3 | F-10 | F-1 | F-6 | F-5 | — |
| 165 | The Calorizing Co. | Calite | S-28 | B-28 | A | | N | — |
| 180 | Chicago Steel Foundry Co. | Pyrasteel | — | Special 2000 | 20 | — | — | — |
| 240 | Driver-Harris Co. | — | | Cimet | Chromax | Nichrome | — | Nichrome V |
| 245 | The Duraloy Co. | Duraloy | A | N | | — | — | — |
| 260 | Electro Alloys Co. | Thermalloy | D | E | B | 72 | A | 80 |
| 268 | The Fahralloy Co. | Fahralloy | F-3 | F-10 | F-1 | F-5B | F-5 | F-6 |
| 285 | General Alloys Co. | G-Alloy | C-1 | CN1-H | X-B | B | A | — |
| 305 | Hoskins Mfg. Co. | Chromel | — | — | 502 | C | B | A |
| 365 | Michiana Products Co. | — | 55 | 100 | Zonite | Fire Armor B | Fire Armor A | — |
| 370 | Michigan Steel Casting Co. | Misco | 3 | C | Misco Metal | HN-2 | HN-1 | — |
| 380 | National Alloy Steel Co. | NA | 19 | 1 | 2 | 65-A | 65 | — |
| 400 | Ohio Steel Foundry Co. | Fahrite | N-7 | N-3 | N-1 | N-5 | N-6 | — |
| 445 | Standard Alloy Co. | — | 8 | 6 | 3 | 4 | — | — |
| ↑ Code number refers to Index of Alloys in BOOK OF STAINLESS STEELS | Type Composition: | | 30% Cr | 28% Cr 12% Ni | 35% Ni 15% Cr | 60% Ni 12% Cr | 65% Ni 18% Cr | 80% Ni 18% Cr |
| | Microstructure: | | Ferrite | Ferrite + Austenite | Austenite | Austenite | Austenite | Austenite |
| Common Uses: | Chemical Industry, Rabble Arms, Sinter Arms, Lithophone Tubes, Pots | | ↑ | Corrosion Resistant | Heat Resistant | Grids | Grids | Heating Elements |
| | Valves, Fittings, Cement Mill, Paper Mill, Oil Refinery, Stoker Parts, Carrier Blades, Tubes, Dampers, Pots | | | ↑ | Carburizing Boxes, Lead, Salt and Cyanide Pots, Trays, Baskets, Furnace Castings, Hearth Plates, Rolls, Retorts, Rails, Enamelling Buckets | | | |

structure may be a trifle "loose"; at any rate, gases seem to be generated in or penetrate to these portions and build up carbon or corrosion deposits, thus producing pressures that actually flake the surface off at spots or cause the metal to swell in something like a tumor growth.

The action may really be the reverse of frost and ice: Carbon collects in a tiny cavity when the metal is hot and in the expanded condition, and this carbon is hard and unyielding when the metal contracts. Result — a progressive crack. This has occurred in bright annealing furnaces where the atmosphere was deliberately kept as far on the decarburizing side of equilibrium as possible without actually becoming oxidizing.

More than one commentator at the meeting testified that, in his experience, ground or machined surfaces were especially vulnerable when the cut got below the dense, fine-grained skin (although this was contested by one producer). Resistance to oxidizing gases, being a function of a protective oxide layer, should be best at the unbroken surface of the original casting. Any place where the oxide is scraped or worn away periodically, as at a guide, is especially vulnerable.

All united in condemning major repairs by welding, and in expressing a desire to limit the number of welded joints in large muffles too big to cast in one piece. Foundrymen present came to the defense of welds, insisting that joints in new castings, properly made with any of the modern processes (atomic hydrogen, arc or oxy-acetylene), will stand up under ordinary conditions met in heat treating furnaces and ceramic kilns, one citing muffles 20 to 30 ft. long, assembled by welding, that are still in first-class condition after 15,000 hr. of service. They were willing to admit that atmosphere had much to do with this — oxidizing gases are innocuous, but reducing gases are very likely to cause trouble.

Whether wrought materials would be better than castings of similar analysis in these services was questioned. One cited a hanger which had to be quenched while under considerable tension — a peculiar service he believed entirely beyond the capacity of a casting. Some users were satisfied with carburizing boxes welded up from relatively thin plate. The combination of heavy (cast) bottoms and thin (cast or sheet) side walls is often advantageous for boxes which must be handled while hot. Since so many welded boxes have given excellent service, this in itself is evidence that welded joints should not be arbitrarily condemned. The intricacy of the present-day trays and size of the retorts ordinarily prevents the use of forged units, and welded assemblies of plates would have the objections of welds in castings — namely, the difficulty of getting a homogeneous joint, physically and chemically, one that does not induce dangerous heat stresses in the base metal nearby, and one that successfully repels the deposition of carbon.

While the cast structure appears to be definitely superior to rolled metal in creep strength, failures from pure stress come not from creep but from fatigue — that is, repeated overstrain induced by localized temperature changes. However, the present problem is largely one of deterioration starting at minor surface discontinuities and interior porosities, and the alloys in wrought condition should theoretically be sounder and therefore more stable, but there was no actual experience cited to bear this out; likely it would rest on the comparative excel-

## Typical Properties of Cast Alloys

H.I. Dixon

| | | C-20 | CN-30 | NC-4 | NC-2 |
|---|---|---|---|---|---|
| Elastic limit (psi.) at room. temp. | | 40,000 | 45,000 | 45,000 | 47,000 |
| Ultimate strength (psi.) | | | | | |
| | at room temp. | 55,000 | 65,700 | 65,000 | 60,000 |
| | at 1600°F. | 19,000 | 18,000 | 16,400 | 21,000 |
| Elongation in 2in. (%) | | | | | |
| | at room temp. | 1.0 | 0.0 | 5.0 | 2.0 |
| | at 1600°F. | 3.0 | 2.0 | 20.0 | 5.0 |
| Machining speed (ft./min.): | | | | | |
| | Carbide tools | 60 | 40 | 50 | 60 |
| | High speed steel | 24 | 10 | 15 | 18 |
| Brinell hardness | | 190 | 180 | 180 | 190 |
| Weight (lb./cu.in.) | | 0.27 | 0.28 | 0.29 | 0.30 |
| Specific gravity | | 7.6 | 7.9 | 8.05 | 8.36 |
| Specific heat at 800°C. (cal./g./°C.) | | 0.145 | 0.14 | 0.135 | 0.126 |
| Thermal conductivity at 800°C. | | | | | |
| | (cal./°C./cm./sec.) | 0.08 | 0.044 | 0.04 | 0.034 |
| | (% of 0.20% C steel) | 75 | 40 | 35 | 33 |
| Average coefficient of linear expansion/°C. Range: 20° to 800°C. | | 0.000012 | 0.000016 | 0.000017 | 0.000016 |
| Suggested design strength | at 1200°F. | 4,700 | 5,000 | 7,000 | 4,400 |
| | 1400°F. | 2,200 | 2,400 | 3,300 | 2,100 |
| | 1600°F. | 900 | 1,000 | 1,500 | 800 |
| | 1800°F. | 200 | 300 | 550 | 200 |
| | 2000°F. | 100 | 125 | 200 | 100 |

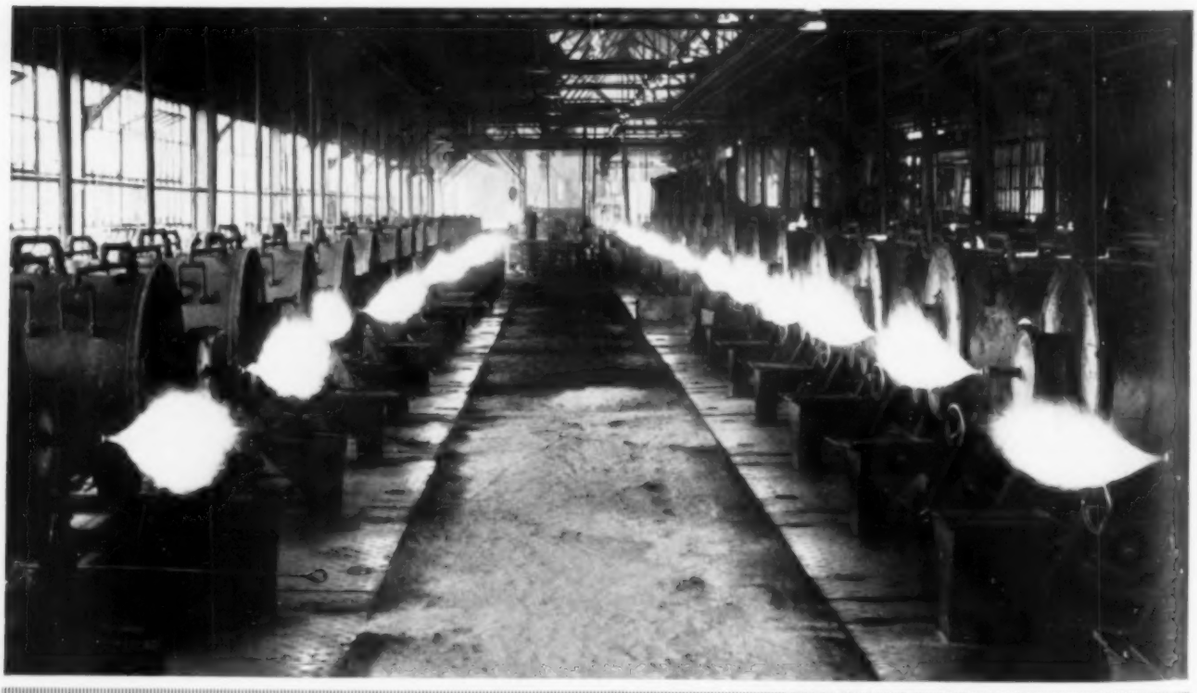
lence of foundry practice versus steel mill and welding practice. One user stated that hearth rollers, centrifugally cast, had been three times as durable as similar castings from sand molds when installed in furnaces in his plant, even when the sand-cast rollers had been machined and proven free from observable surface defects, and believed that the spinning process was such as to localize impurities on the inside of the wall, where they were of least moment.

One point emphasized in the comparison of wrought products to cast was that the former are made with lighter wall sections. If it is granted that the rolled sheet exposed to carbonaceous atmospheres will be carburized at the same rate as the same alloy casting, the thinner wall will be carburized to the very center in a time when the thicker cast box wall retains a generous core, unaffected and still tough. Life and cost comparisons should therefore be made on parts of equal thickness, except, of course, where the advantages of rapid heat transmission through thin walls and smaller mass of packing compound more than pay for the shorter life of thinner sheet alloy.

While one opinion held that the correct solution of the controlled atmosphere problem would require the discovery of entirely new alloys resistant to hydrogenation and carburization, the foundrymen present cited the undoubted improvement in life of currently produced castings to indicate that eventual success would be achieved with alloys of the present conventional types, based on nickel, chromium and iron, and with such additions as molybdenum, aluminum and titanium to improve high temperature strength and refine the grain. Any new alloy must fill three fundamental requisites: *(a)* Castability; *(b)* resistance to atmospheres without change either in the casting or the atmosphere by catalytic reaction; *(c)* adequate strength at working temperatures, retained for long periods of time. The Alloy Casting Industry is now financing a comprehensive investigation at Battelle Memorial Institute of the properties of standard compositions and a research into the improvement of existing alloys.

May we not also look for an improvement in the atmospheres? If soot is a determining cause of mechanical failure, a non-sooting gas would be a distinct step forward. Likewise circulation may have something to do with it—atmospheres which are relatively stagnant appear to be the more destructive.

*In Heat Treatment Plants Such as This, Life of Alloy Parts Is a Matter of Great Concern. Courtesy Timken Roller Bearing Co.*





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# Physical Constants of Purest Zinc

(Compiled by Research Division, New Jersey Zinc Co.)

Note: Purity stated is that reported for metal used in preparing test pieces; actual composition of latter is infrequently given

## Constants Affected by Orientation

### Unit Cell Dimensions (Angstrom Units)

| Reference: | 13 | 2 |
|---|---|---|
| Purity: | Spectroscopic | 99.99+% |
| Temperature: | 25°C. | 27°C. |
| a | 2.6597 | 2.6600±0.0002 |
| c | 4.9367 | 4.9379±0.0005 |
| c÷a | 1.8561 | 1.8563 |

### Coefficient of Expansion

| Reference: | 8 | | 4 | |
|---|---|---|---|---|
| State: | Single Crystal | | Polycrystalline Casting | |
| Purity: | Spectroscopic | Kahlbaum's Best[a] | 99.993% | |
| Direction: | 44° to Principal Axis | 0° to Principal Axis | | |
| 0 to 50°C. | 4.00×10⁻⁵ | [b] 5.46×10⁻⁵ | | |
| 0 to 100 | 4.04 | 5.70 | 20 to 100 | 3.95×10⁻⁵ |
| 0 to 150 | 4.23 | 5.74 | 20 to 150 | 3.96 |
| 0 to 200 | 4.40 | 5.80 | 20 to 200 | 3.97 |
| 0 to 250 | 4.55 | 5.81 | 20 to 250 | 3.97 |
| 0 to 300 | 4.60 | 5.73 | | |

(a) Contains 0.014% Pb, 0.012% Cd
(b) Reference 9 gives 5.74 at 18°C., and 1.26 for perpendicular direction

### Thermal Conductivity

Reference: 7
State: Single Crystal
Purity: 99.993%

| Temp. | Cal./sec./cm./°C. |
|---|---|
| -200°C. | 0.36 |
| -150 | 0.34 |
| -100 | 0.33 |
| -50 | 0.32 |
| 0 | 0.30 |
| +50 | 0.29 |
| +100 | 0.28 |

### Magnetic and Electrical Properties

| | Magnetic Susceptibility | | Resistivity (ohms/cu.cm.) | | | Temp. Coefficient of Resistivity | |
|---|---|---|---|---|---|---|---|
| Reference: | 10 | | 11 | | 4 | 12 | 4 |
| State: | Single Crystal | | Single Crystal | | Swaged Polycrystalline Wire | Single Crystal | Wire, Swaged and Drawn |
| Purity: | Chemical | | Spectroscopic | | Spectroscopic | Spectroscopic | |
| Direction: | 0° to Hexagonal Axis | 90° to Hexagonal Axis | 0° to Hexagonal Axis | 90° to Hexagonal Axis | | 1° to 86.5° to Principal Axis | |
| Temp. | — | — | 20°C. | 20°C. | 20°C. | -170 to 25°C. | 0 to 100°C. |
| Constant | -1.90×10⁻⁷ | -1.45×10⁻⁷ | 6.16×10⁻⁶ | 5.83×10⁻⁶ | 5.916×10⁻⁶ | 4.058×10⁻³ (average) | 4.19×10⁻³ |

## Constants Not Known to Be Affected by Orientation

### Thermal Electromotive Force (Zn-Pt Thermocouple)

Reference: 4
State: Cold Drawn Wire
Purity: Spectroscopic

| Temp. | Millivolts |
|---|---|
| 0°C. | 0.000 |
| 50 | 0.331 |
| 100 | 0.758 |
| 150 | 1.276 |
| 200 | 1.894 |
| 250 | 2.610 |
| 300 | 3.417 |
| 350 | 4.310 |
| 400 | 5.290 |
| 415 | 5.604 |

### Specific Heat

Reference: 6
Purity: 99.948%

| Temp. | Cal./g./°C. |
|---|---|
| 100°C. | 0.0946 |
| 200 | 0.0961 |
| 300 | 0.0981 |
| 400 | 0.1002 |
| 500 | 0.1522 |
| 600 | 0.1473 |
| 700 | 0.1444 |
| 800 | 0.1423 |

### Density, Melting and Boiling Points

| State | Purity | Temp. | Density g./cu.cm. | Reference |
|---|---|---|---|---|
| Density: | | | | |
| Cast | 99.993% | 25°C. | 7.131 | 3 |
| Rolled | 99.993% | 25 | 7.142 | 2 |
| Swaged wire | Spectroscopic | 25 | 7.133 | 4 |
| Molten | 99.94% | 419.4 | 6.92 | 2 |
| Melting Point | Spectroscopic | 419.47 | — | 4 |
| | Spectroscopic | 419.45 | — | 2 |
| | 99.993% | 419.48 | — | 5 |
| Boiling Point at 760 mm. pressure | | 905°C.±2 | — | 1 |

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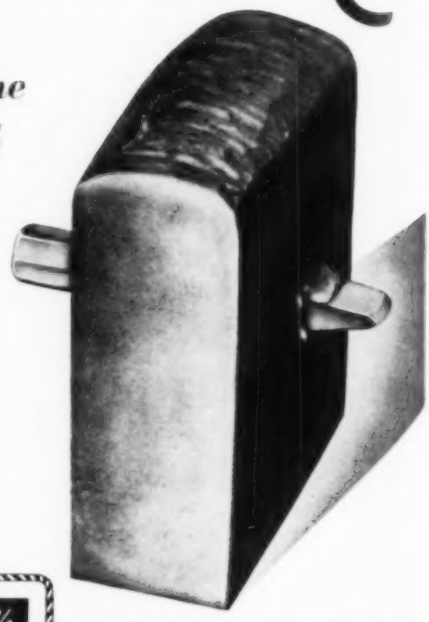
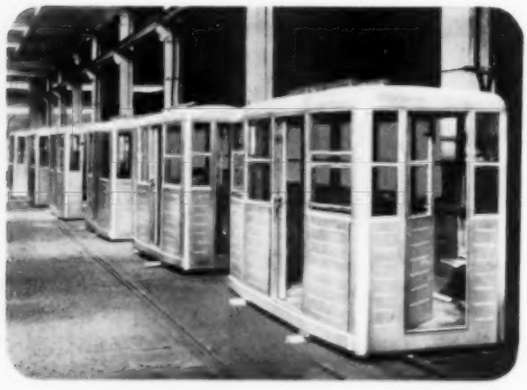
# SIMPLE ARITHMETIC

## ...proves the ECONOMY of the NICKEL ALLOY STEELS



**15 x 1 = 15 times Longer life**

Multiply the life of a tool and you subtract from the ultimate cost. And a case where tool life was increased 15 times by the simple expedient of Nickel alloy steel in one large industrial plant is indeed a case in point. The chisel driven cold through this loaf-like block of mild steel is simply a dramatic demonstration of its capabilities, but the part of the story that is most interesting to the treasury's watchdog is the fact that it showed a service life 1400% greater than the plain carbon steel type formerly used. The increased strength, toughness, wear-resistance, and shock-resistance obtained with the Nickel alloy steels quickly compensate for the slightly higher initial cost.



**100% – 56% = 44% of former weight**

Dead weight is a wastrel. It squanders power in many an application, subjects machinery to unnecessary stress, wear and fatigue. But Piaggio & Co. of Genoa, Italy, solved the problem of useless weight in the same way that scores of railroads are now doing. They used stainless steel for these aerial railway cars destined for use in the Italian Alps. Fabricated under license of the Edward G. Budd Manufacturing Co. of Philadelphia, these cars when completed weighed 56% less than the type formerly used. The composition employed was the popular "18-8" chromium-Nickel steel which possesses an unusually high strength-weight ratio.

**16 – 15 = 1 Survivor**

Plow discs of the type pictured here take a terrific beating from shocks and abrasion. A prominent manufacturer, Ingersoll Steel and Disc Division of Borg-Warner Corp., recently developed a steel for this purpose, having all of the requisite properties for long service life against breakage. Composition is known as "Super-Alloy" and contains from 1 to 1½% Nickel, a fact that explains its unusual endurance. Demonstration of its superiority was recently made when a harrow disc plow came to this manufacturer's attention with 15 of its 16 discs broken. Analysis brought to light that the 1 survivor was made of "Super-Alloy", the composition containing Nickel.

*We invite consultation on the use of the Nickel alloy steels in your equipment.*

# NICKEL ALLOY STEELS

**THE INTERNATIONAL NICKEL COMPANY, INC., NEW YORK, N. Y.**

# Letters from Abroad

## Improvement of Arc-Furnace Roofs

TURIN, ITALY

*To the Editor of* METAL PROGRESS:

Much attention has been given by European steel works during the past ten years to the problem of improving the physical and chemical properties of refractories used for roofs of electric furnaces. The great increase of the percentage of electric steel to the total steel output, and the still more rapid increase of the percentage of special and alloy steels, have given a great impulse to researches in this field of high grade refractories.

Silica brick is by far the most generally used refractory material, but the present severe requirements — from the thermal, physical and chemical points of view — of the new processes for manufacturing high quality special steels are continually increasing the troubles connected with furnace roofs.

For the time being, all the European efforts to find a better substitute for this particular application have unfortunately given very few satisfactory results. Furthermore, the real practical value of the improvements which may have been effected can hardly be appraised on account of the very different conditions under which the individual tests have been made.

A first cause of uncertainty when trying to compare the technical and economic results obtained with new materials lies in the fact that it is very difficult to fix the real *normal* duty of the present standard material, namely silica brick, which should form the basis for every practical comparison. In fact, if we take only the data concerning the number of heats obtainable with a roof of silica brick for electric furnaces of a given design and a given size, we find — both from technical papers and from information collected directly in different works — figures varying within astonishingly wide limits. Though this uncertainty is explained by the great variety of working conditions, still the fact remains that such data can hardly be taken as a basis for establishing reliable comparisons.

An example of this situation can be found by comparing the data contained in three very interesting papers on this subject published in *Stahl und Eisen* (1930, p. 800; 1932, p. 897; and 1936, p. 1000) and especially in the discussion following the last paper. While it is stated that the roof of a 10-ton arc furnace, made with tar and rammed burned dolomite, could stand between 10 and 15 heats, many French and Italian furnaces of the same size could be quoted, making 30 to 40 heats under roofs of the same material. An explanation of these large differences can only be found in the completely different working conditions.

Similar remarks can be made about the results obtained with chromite bricks. In some instances quoted in the above papers the results have been completely unsatisfactory. Nevertheless, chromite roofs are used with excellent results, both technical and from a cost standpoint, by various European works, where the only objection lies in the fact that small quantities of chromium are absorbed by the liquid steel bath.

The great importance of the problem of improving the quality of refractory materials for roofs of electric furnaces cannot be overestimated. On the other hand, even a superficial study of the published experimental results and comparison of such results with many well-

known facts of experience are sufficient to show that the trials made under the conditions so far adopted (namely, experimental conditions inadequately defined, and not corresponding to actual industrial practice) cannot lead to results of any practical value.

To attain useful results it seems that a more complete and regular cooperation would be necessary between the leading manufacturers of refractories and the steel works.

FEDERICO GIOLITTI
Consulting Metallurgical Engineer

## Status of Welding in Europe

EAST PITTSBURGH, PA.

*To the Editor of* METAL PROGRESS:

Observations made during a six-months stay in Europe (principally in England) indicate that welding has grown over there to be as important a tool in engineering as it has in the United States. To draw definite conclusions as to the state of advancement of the welding art in different countries is difficult. Certain industries are somewhat backward, but the same could be said of our own country. Other industries can match their work and welding processes with the best in the United States. The production of resistance welded tubing in England at the rate of 65 ft. per min. and the use of welding manipulators in Holland to rotate a complete rail coach to facilitate all down-hand welding are examples of developments that will match the best we can show.

Welding machines in Europe are of high quality. In most countries the use of alternating-current equipment far surpasses the use of direct-current welding generators. Special attention has been directed to low rating machines for thin gage welding, with the consequence that very excellent sets using rectifiers have been developed.

Welding electrodes in Europe are primarily of the shielded-arc type although considerable bare and light-dipped electrodes are still in use in Germany and France. There are many more makes of electrodes in Europe than there are in America, but even the best do not seem to compare in quality or performance to those manufactured in the United States.

Spot welding and other types of resistance welding are not in common use as they are in America. There is a great interest in such methods of welding, however, particularly for automobile, aircraft and railway construction. One automobile manufacturer is at the present time considering the installation of equipment of special types for the production of duralumin bodies.

Gas welding, cutting and brazing are in use and very good results are being obtained on all types of metals. Fabricated parts made from aluminum 1 in. thick have been welded with oxy-acetylene flame.

The industries in which welding is being used are about the same as in the United States. Ships, buildings, bridges, railway coaches, automobiles, busses, elevators, pressure vessels and all engineering equipment are now being fabricated by welding.

CHARLES H. JENNINGS
Research Department
Westinghouse Electric & Mfg. Co.

## Austenitic Cr-Mn Steels Are Unusually Creep Resistant

JUDENBURG, AUSTRIA

*To the Editor of* METAL PROGRESS:

As has been pointed out by Dr. Maurer in letters to METAL PROGRESS (May 1937, for instance), European development of the high chromium-manganese steels started soon after the invention of the non-corroding 18-8 chromium-nickel steels and was based on the idea of replacing nickel by its equivalent manganese. Such 18-9 chromium-manganese steels show a heterogeneous microstructure of alpha and gamma crystals. [Note Dr. Becket's remarks on this matter, p. 274.—EDITOR]

From the standpoint of commercial applications it was found that they are markedly less resistant than 18-8 chromium-nickel steels to many acids and salt solutions. Furthermore, intercrystalline corrosion has been found, even when carbon was very low or was bound by additional carbide-forming elements such as titanium, niobium or tantalum. There must consequently be a second factor involved, which promotes the formation of a presumably manganese-rich intergranular substance, more soluble in strong corrodants than the alpha or gamma solid solutions. It also seems that this intergranular corrosion must be held responsible for the wide difference in behavior, under the same corrosion conditions, of various chromium-manganese steels having practically the same composition.

Despite these drawbacks this group of steels has been greatly improved by adding

molybdenum, nickel and copper, so that they are now able to compete with 18-8 chromium-nickel in an extended range of applications.

Chromium-manganese steels of simple austenitic structure have been developed at a much later date. Their chromium content cannot exceed 15% without the formation of an excessively brittle compound (probably FeCr in which some chromium is replaced by manganese). Their heat resistance is not very good at temperatures over 850° C. They also can withstand only the rather weak acids and salts.

Their industrial application, however, is assured by their high resistance against sulphurous gases, and especially by a surprising creep resistance, which in the range between 500 and 700° C. surpasses that of even the 18-8 chromium-nickel steels alloyed with molybdenum. It has been stated that molybdenum, copper and tantalum-niobium will further increase the creep resistance of these austenitic chromium-manganese steels, but the sharply decreased toughness and the inclination to intercrystalline rupture in temperature ranges over 700° C. militates against the use of such further alloys. A better substitute is nitrogen (from 0.10 to 0.30%); such steels show the highest values of creep resistance known to the writer. With the partial substitution of silicon for some of the chromium, a new alloy was found to be heat resistant up to 1200° C. (2200° F.). Its use may be somewhat restricted by an impaired resistance to impact after annealing between 600 and 850° C. (1100 to 1550° F.).

Another austenitic steel with equal chromium and manganese content is used in Austria in the form of deep drawing sheet for food handling equipment. Corrosion resistance is secured by additions of nickel, molybdenum or by copper. Their silver-like luster is very agreeable when used for knives, forks, platters, chafing dishes and the like.

The latest alloys developed on the Cr-Mn base are useful for non-magnetic parts. Their carbon content is very low to impart good machinability. Their high manganese content, 25 to 40%, in combination with about 7% of chromium, gives a very high elastic ratio after a simple forging operation, with or without a slight anneal. The ratio of the 0.2% elastic limit to the ultimate strength is as high as 96%. Similar results are had by substituting from 0.10 to 0.30% of nitrogen for several per cent of manganese.

The development of steels based on the chromium-manganese system has therefore advanced at a very good rate in Europe, and has already brought out not only some very interesting special steels, but also means of improving welding practice in special jobs.

HANS K. LEGAT, *Dr-Ing.*
Steiermark Steelworks

## A Formula for Creep Curves

PARIS, FRANCE

*To the Editor of* METAL PROGRESS:

Recent years have been marked by an abundance of research work, carried on in every country, on the mechanical properties of metals at high temperature. Most of these studies have centered on the elongation or growth under load at constant temperature — a method variously designed as viscosity tests, creep tests, flow tests, and so on. In spite of a general uniformity of the testing method, it is not easy to compare results and come to any conclusion in regard to the factors influencing hot deformation, or to the practical applications of the data.

This may be attributed to two circumstances: (1) The form of the time-elongation curve has not yet been defined, and (2) different arbitrary parameters have been used to define the time-elongation curve by different investigators and in different countries. The rectilinear form obtained by plotting test data on logarithmic coordinates allowing its entire definition by an equation with two coefficients has been criticized by various authors, so that mean values have been adopted to define elongation rates either corresponding to the quasi-rectilinear part of the curve, taken between the 25th and 35th hr., between the 24th and 72nd hr., or between the 35th and 45th day. Using these intervals, the limiting stress has been defined as the limit for which the rate, in these different intervals, is less than various assumed values — that is, per hr.: $10^{-6}$ (Hatfield), $5.10^{-6}$ (Mailander and Centre d'Etudes du Bureau Veritas), $10.10^{-6}$ (Verein deutscher Eisenhüttenleute), $15.10^{-6}$ (Pomp), or even $10^{-5}$ per day (Tapsell). This has given rise to the various terms "limiting creep stress," "time yield," "*Dauerstandfestigkeit*," "*limite de viscosité*," and "*limites des écoulements limités*."

On the other hand, investigators have recognized that even when the usual characteristics defining a metal are nearly identical (chemical composition, heat treatment, mechanical properties at ordinary temperatures, and so

on), its behavior at high temperature may still be different. They are therefore tending toward longer and longer tests, progressing from 24 to 72, then to 1200 hr, and even far more, on the assumption that the phenomena may never be completely determined.

Thus, we find ourselves in an inextricable situation between two extremes: (1) Either adopt long-time tests which must naturally be very limited in number and therefore cannot exercise complete control nor give complete guarantee as long as the ordinary short-time properties mentioned above are not competent for acceptance or (2) multiply direct control by means of short-time tests, which are not considered sufficient to forecast the complete and eventual behavior at high temperature. In any event, no security is offered, according to current opinion, regarding the behavior of metal working at high temperature.

Under these conditions, the proper representation of the time-elongation curves, even if empirical, by means of a formula containing only a few parameters, would present immense advantages. In the first place, these parameters would furnish numerical means for comparing tests and operators, and also for evaluating the factors influencing strength at high temperature. In the second place, short-time tests could be made in the interval required for the correct determination of parameters which could be extrapolated to longer duration without actually carrying out the tests. Finally, secondary factors could be segregated from the principal phenomena.

Lacking complete knowledge of the mechanism of hot deformation and thus being unable to furnish a complete analytical expression therefor, M. de Lacombe tried various empirical formulas and has attained some very good results by using the following representation:

$$y = y_o + at^m + bt^n$$

in which $y$ is the recorded elongation, $t$ the time, $y_o$, $a$, $b$, $m$, $n$ are coefficients among which $m$ is less than 1 (usually in the neighborhood of 0.3 to 0.5) and $n$ is more than 1 (usually between 1.8 and 2.2).

The first two terms $y_o + at^m$ represent curves having only one part concave to the time axis. Cold drawing (spontaneous hardening) has a retarding effect on creep and the coefficient $m < 1$ characterizes this cold drawing. The term $bt^n$ occurs only when the time-elongation curve turns upward at extended time, with a linear portion or even a concave hook turned toward the $y$ or elongation axis; it may be said that the coefficient $n > 1$ indicates a "negative cold drawing" or acceleration of the internal mobility by deformation. When $m = 1$, the deformation is purely viscous, according to Maxwell, and the curve is a straight line; in this case the coefficient $a$ is the deformation rate of an ideally viscous body.

The nearly rectilinear region of the experimental curves would thus appear to be the result of a pseudo-compensation between the two terms containing $t$.

This formula has been applied, with an accuracy equal to the ability to read the diagrams, to certain results published by Cross and Dahle, Chevenard, Pomp and Länge, as well as to those obtained at the laboratories of the Aciéries d'Ugine used in the development of the formula. It therefore is competent to represent results of a large number of tests varying in duration from 3 to 5000 hr.

It remains to be seen whether this formula is of general applicability. It would then permit numerical comparisons to be made of the results obtained in different laboratories.

Furthermore, by this formula may be calculated the instantaneous initial elongation, $y_o$, which is, in fact, always lower than the value assigned to it by extrapolation of the curve toward the origin (especially when $m$ has a low value).

By taking the first differential of $y$ in regard to $t$, the rate of extension as a function of time may be determined.

ALBERT PORTEVIN
Consulting Engineer

## Modern Malleable Practice

HARVEY, ILLINOIS

*To the Editor of* METAL PROGRESS:

The article "Faster Annealing of Malleable Cast Iron" which appeared in your January 1938 issue prompts a few comments on behalf of those who are responsible for achievements in the art or technique of malleable casting which are second to none during the past 35 years. Those who know what has been accomplished since 1903 will bear me out in the statement that as much has been done in improvement of product and process as in the steel or gray iron industries.

My close contact with malleable since 1901 continuously to this date, prompts the statement

that annealing time under 96 hr. is not of primary commercial importance, and is worth striving for only if it can be attained without increase in cost of product.

Reference by the authors to the duplexing process in melting warrants quotation from an article by the writer which appeared in *The Iron Age*, issue of September 8, 1932, under the title "The Malleable Industry Since 1900":

> "Duplexing provides continuous metal and this in turn makes possible continuous molding and pouring. The cupola is the lowest cost melting unit we have and, for tapping a low carbon metal, the cost of charge is much lower than that for the air furnace in direct melting by that method.
>
> "Combining the reduced cost of melting and of cupola charge with the savings in molding and pouring costs with continuous production, we have the potentialities for very low malleable casting costs if, as, and when there is steady business in sufficient volume to provide operation of such plants on a normal schedule.
>
> "Assuming a normal annual demand for 800,000 tons of castings—average for the past nine years: 784,555 tons—there is one duplexing foundry in Michigan which is capable of producing approximately 10% of the entire requirement and one in Ohio with capacity for approximately 6%. These two, producing one-sixth of the tonnage."

Statistics on melting methods of the malleable industry, revised as of January 25, 1938, are given below:

| Melting Method | Annual Tonnage Capacity | Per Cent of Capacity |
|---|---|---|
| Pulverized coal fired air furnace | | |
| Direct | 728,850 | 61.5 |
| Duplexing | 144,900 | 12.2 |
| Hand-fired air furnace | 56,800 | 4.8 |
| Cupola | 97,200 | 8.2 |
| Cupola and electric furnace | | |
| Duplexing | 100,000 | 8.5 |
| Oil-fired air furnace | | |
| Direct | 24,600 | 2.1 |
| Duplexing | 14,200 | 1.2 |
| Openhearth furnace | 18,000 | 1.5 |
| Total | 1,184,550 | 100.0 |

Totaling the three items of duplexing we find that 22.9% or nearly one-fourth of existing capacity is now duplexed, this representing 12 foundries so equipped for all or a major part of their capacity.

Although a strong advocate of this method of melting, I cannot subscribe to the statement that duplexing "gives closer chemical control of the iron." It does give the control necessary for production of the standard composition but closer conformity to a given range in elements is possible from direct melting air or reverberatory furnaces.

I can and do subscribe to the second advantage mentioned, namely, that duplexing permits superheating, and quote from a paper entitled "Developments in Melting Malleable Cast Iron" appearing in *Transactions*, American Foundrymen's Association, Vol. 45, (1937).

> "A not generally recognized metallurgical fact should be mentioned here because of the significance which this has in the duplexing field. This relates to the carbon effect on graphitization in solidification and also the carbon effect upon physical properties of the metal. As the writer is not now associated with a producer it is necessary for him to speak from general observations rather than from actual quantitative data on these points. As a result of rather extensive observation, he would estimate that for a given section of metal or weight of castings, carbon may be 10 to 20 points higher in duplexed metal than in direct-melted metal, without deterioration in quality.
>
> "The metallurgical difference between duplexed malleable and direct-melted malleable iron of similar compositions is one of the conundrums of the malleable process. It is our opinion that the difference is to be accounted for by the difference in charge materials used in the two methods, more steel scrap and less pig iron being used in the duplexed metal than in the direct-melted metal. In other words, "inheritance" from the charge affects the carbon condition or dispersal in the structure."

To the third advantage mentioned ("it lends itself most conveniently to continuous pouring") I subscribe also, except that this method is no longer limited to the large tonnage foundries, it being applicable down to a daily melt of as little as 10 tons—or even less under certain conditions.

So long as we confine the discussion to the standard malleable product and physical properties as given in table on page 36, I have little exception to the statements made except to call attention to the fact that gas is not available universally at a cost to make the type of equipment described the economic unit in many of the malleable foundries.

Having gone on record with the malleable industry as favoring the elimination of packing

materials for much of the present physical requirement, where cold deformation is not essential, and the elimination of the conventional annealing pots and bottoms, I must be consistent and favor changes in annealing equipment where cost per ton of castings annealed will permit. Again let me point out that *total* annealing cost must be the measure, with 96-hr. time the dividing line.

Very substantial tonnages of castings are being annealed in periodic floor type ovens of insulating refractory construction and in car type ovens with fuel costs well under $1.00 per ton and other items in proportion.

The muffle type oven has not become popular principally because the cycle in this type is longer than in the conventional pot type oven. Slow heating with an even slower cooling and the necessity for dropping temperature to a very low point for removal of castings makes the cycle unduly long. Notwithstanding this fact, at least two American malleable foundries anneal practically their entire production in the muffle type of ovens.

It does not follow, however, that continuous muffles or even cartype with special provisions for firing and for heat transfer may not be the solution where gas and coal are not on an equivalent heat-cost basis. Surface finish and quality of muffle annealed castings are both of the highest order.

Annealing methods now in effect in American foundries, revised as of January 25, 1938, are given in the tabulation below:

| Method of Firing | Annual Casting Tonnage | Per Cent of Capacity |
|---|---|---|
| Pulverized coal fired | 536,400 | 45.2 |
| Coal, hand-fired | 159,200 | 13.5 |
| Tunnel kiln* | 226,500 | 19.1 |
| Oil fired | 180,950 | 15.3 |
| Gas fired | 43,500 | 3.7 |
| Electric | 38,000 | 3.2 |
| Totals | 1,184,550 | 100.0 |

*Continuous radiant tube capacity included.

Because of the already too great length of this communication, I shall refrain from discussion of some of the interesting technical points in atmosphere control, gases evolved by the product and effect of weight of castings per cubic foot of casting space on annealing cost; also the arguments for and against the two types, continuous and periodic.

W. R. Bean
Vice-President, Foundry Equipment Division
Whiting Corporation

## Metallurgy and Civilization, 1938

Montreal, Canada

*To the Editor of* Metal Progress:

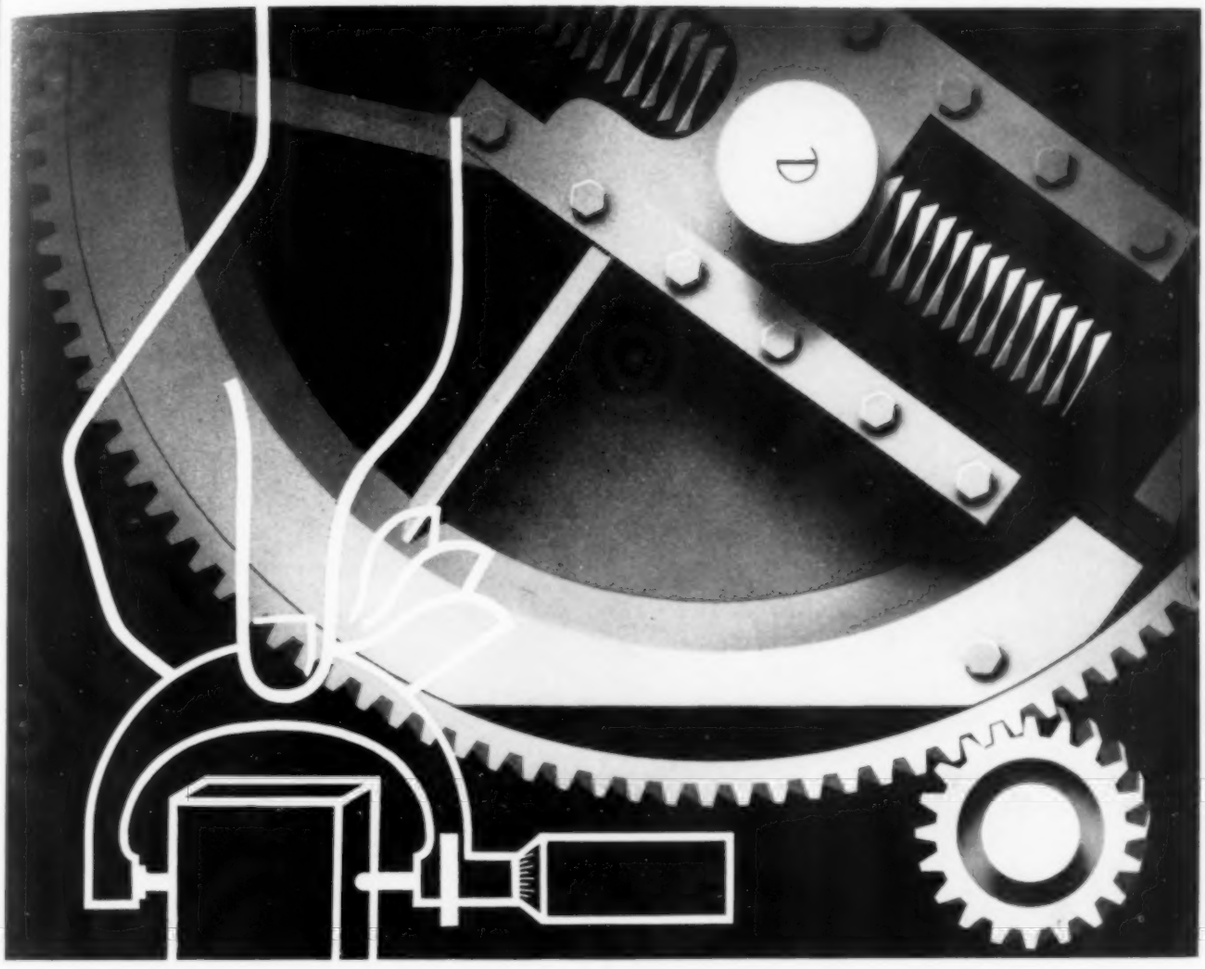
I have been wondering if many ASM members have seen the striking tribute to metallurgy and metallurgists contained in Chapter 57 (on the Development of Material Knowledge) in the interesting "Short History of the World" by the eminent English writer H. G. Wells. Possibly the fact that Mr. Wells earned a modest living as an engineer before he achieved fame and wealth as a writer prompted him to say, "Nothing in the previous practical advance of mankind is comparable in its consequences to the complete mastery over enormous masses of steel and iron and over their texture and quality that man has now achieved."

Bernard Collitt
Metallurgist
Jenkins Bros., Ltd.

### A Longer Extract from Mr. Wells

Throughout the 17th and 18th centuries a steady growth of knowledge was in progress in the Europeanized world. There was much clearing up of general ideas about matter and motion, much mathematical advance, a great revival of science. . . This reacted upon metallurgy. Improved metallurgy, affording the possibility of a larger and bolder handling of masses of metal and other materials, reacted upon practical inventions. Machinery on a new scale and in a new abundance appeared to revolutionize industry. . . By the middle of the 19th century a network of railways had spread all over Europe, they reduced the chief European distances to about a tenth of what they had been. They made it possible to carry out administrative work in areas ten times as great as any that had hitherto been workable under one administration. The full significance of that possibility in Europe still remains to be realized. Europe is still netted in boundaries drawn in the horse and road era. . .

The steam railway and the electric telegraph were to the popular imagination of the middle 19th century the most striking and revolutionary of inventions, but they were only the most conspicuous and clumsy first fruits of a far more extensive process. Technical knowledge and skill were developing with an extraordinary rapidity and to an extraordinary extent, measured by the progress of any previous age. Far less conspicuous at first in everyday life, but finally far more important was the extension of man's power over various structural materials. Before the middle of the 18th century iron was (*Continued on page 294*)



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# Personals

**Robert Sergeson** ⊜, for the past eight years director of the metallurgical laboratory for the Canton and Massillon plants of Republic Steel Corp., has joined the staff of Crucible Steel Co. of America as chief metallurgist of the Park Works, Pittsburgh.

**S. K. Oliver** ⊜, metallurgist for Delco Products Corp., has been transferred to the Electro-Motive Corp., La Grange, Ill., to take charge of heat treating in the new diesel engine plant.

Appointed as representative of A. F. Holden Co. in the territory of northern Illinois, Wisconsin, Iowa and Minnesota: **J. B. Carey,** formerly chief metallurgist of the New Process Gear Corp., Syracuse, N. Y.

**W. H. Rice** ⊜, formerly with Wellman Engineering Co., Cleveland, has received an appointment to teach welding and metallurgy at Oklahoma Agricultural and Mechanical College.

**H. Ross Belding** ⊜ has been promoted to chief metallurgist, Farrell Works, Carnegie-Illinois Steel Corp.

**Ernest E. Wachsmuth** ⊜ has left his position as technical adviser for Revere Copper and Brass, Inc., Detroit, to become consulting engineer for Leipzig Trade Fair, Inc., New York.

**Gerald D. Howk** ⊜ has been appointed mill representative in the Cincinnati territory for Ludlum Steel Co.

Appointed field metallurgist for the Hartford, Conn., sales district by Union Drawn Steel Division, Republic Steel Corp.: **J. L. Stone** ⊜, formerly metallurgist for the Massillon plant of Union Drawn.

**Oscar E. Swenson** ⊜ has been made research metallurgist for Chicago Steel & Wire Co.

**Paul Klain** ⊜, formerly with Packard Motor Car Co., has been made research associate in metallurgy, Battelle Memorial Institute, Columbus, Ohio.

**G. W. Garn** ⊜, formerly metallurgist at Kalamazoo plant of Fuller Mfg. Co., has been made superintendent of the Unit Drop Forge Division at Milwaukee.

Re-elected by the board of directors of Despatch Oven Co.: **A. E. Grapp,** president; **H. L. Grapp** ⊜, vice-president and general manager; **C. P. Doherty,** vice-president and production manager; **G. C. Keyes,** vice-president and chief engineer; **F. H. Raber,** secretary, sales manager.

Honored with the degree of Doctor of Science by Temple University: **Henry Butler Allen** ⊜, secretary and director of The Franklin Institute, Philadelphia.

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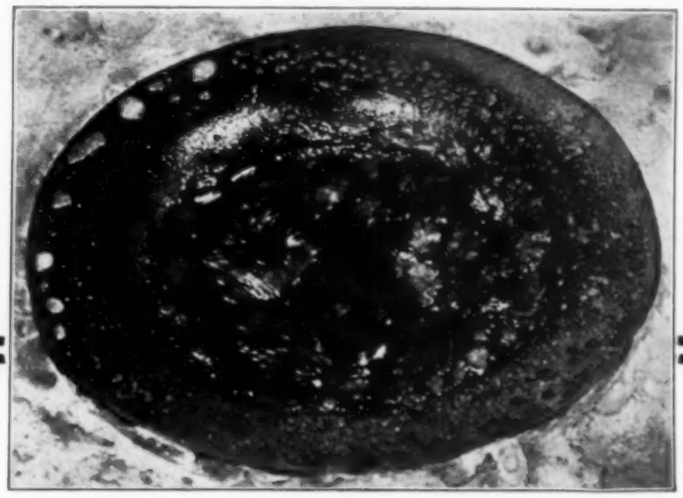

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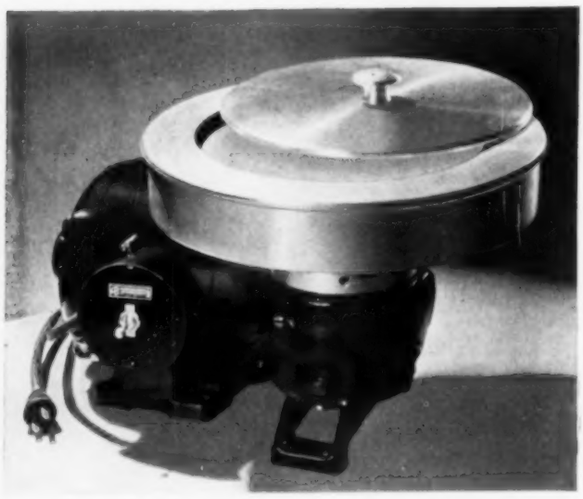

● Recent findings by metallurgists in research bring to view specific advantages in polishing metallographic specimens at low speeds. The A-B Low Speed Polisher shown above meets the requirements of those who want these advantages in this phase of specimen preparation. It is a highly efficient and sturdily built equipment and embodies desirable use-conveniences.

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AB

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## Civilization, 1938

(*Continued from page 288*) reduced from its ores by means of wood charcoal, was handled in small pieces, and hammered and wrought into shape. It was material for a craftsman. Quality and treatment were enormously dependent upon the experience and sagacity of the individual iron-worker. The largest masses of iron that could be dealt with under those conditions amounted at most (in the 16th century) to two or three tons.

The ancient world, because of its metallurgical inferiority, could not use steam. The steam engine, even the primitive pumping engine, could not develop before sheet iron was available. The early engines seem to the modern eyes very pitiful and clumsy bits of iron mongery, but they were the utmost that the metallurgical science of the time could do. As late as 1856 came the bessemer process, and presently (1864) the openhearth process, in which steel and every sort of iron could be melted, purified and cast in a manner and upon a scale hitherto unheard of. Today in the electric furnace one may see tons of incandescent steel swirling about like boiling milk in a saucepan.

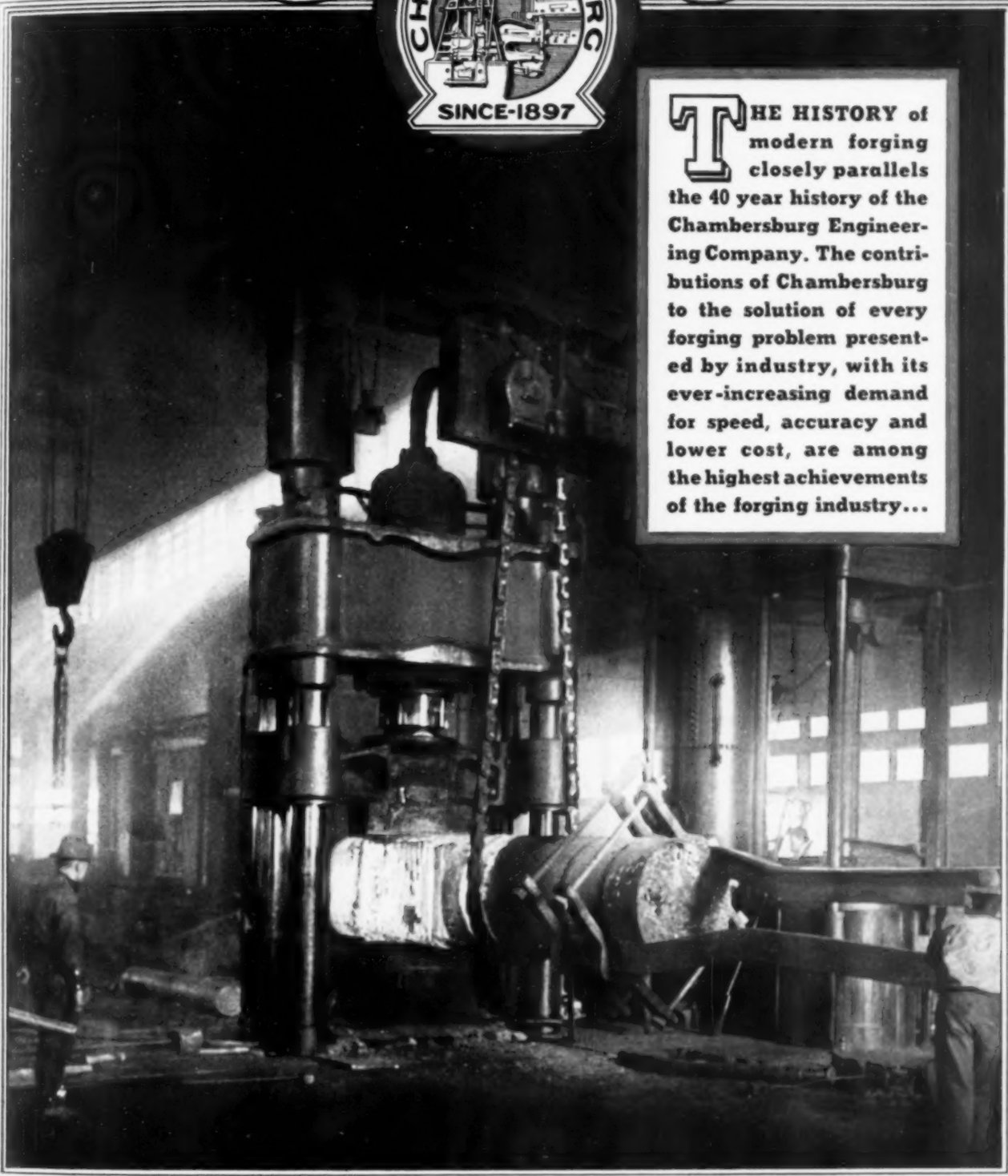
Nothing in the previous practical advances of mankind is comparable in its consequences to the complete mastery over enormous masses of steel and iron and over their texture and quality that man has now achieved. The railways and early engines of all sorts were the mere initial triumphs of the new metallurgical methods. Presently came ships of iron and steel, vast bridges, and a new way of building with steel upon a gigantic scale.

Before the 19th century there were no ships in the world much over 2000 tons burden; now there is nothing wonderful about a 50,000-ton liner. There are people who sneer at this kind of progress as being a progress in "mere size," but that sort of sneering merely marks the intellectual limitations of those who indulge in it. The great ship or the steel frame building is not, as they imagine, a magnified version of the small ship or building of the past; it is a thing different in kind, more lightly and strongly built, of finer and stronger materials; instead of being a thing of precedent and rule of thumb, it is a thing of subtle and intricate calculation. In the old house or ship, matter was dominant — the material and its needs had to be slavishly obeyed; in the new, matter had been captured, changed, coerced. Think of the coal and iron and sand dragged out of the banks and pits, wrenched, wrought, molten and cast, to be flung at last, a slender, glittering pinnacle of steel and glass, 600 ft. above the crowded city!

Fortieth Year

CHAMBERSBURG

SINCE-1897



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If you want more information on what Park-Kase can do for you . . . *write us.*

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| Carburizers | Quenching Oils |
| Lead Pot Carbon | Tempering Oils |
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**DETROIT**


## Stress-Rupture Test

*(Continued from page 268)* metal is affected. The other may be considered as intergranular attack since the grain boundaries are influenced for a considerable depth below the actual surface of the steel. Of these two, the intergranular attack is the more serious both with respect to its profound effect on nearly all the physical properties associated with our idea of "quality," and the difficulty involved in its detection.

The 4 to 6% Cr + Mo steel considered in the bottom diagram on page 267 resisted oxidation under the given test conditions and the relationship between stress and fracture time is expressible by a single straight line at the two lower temperatures, 1000 and 1100° F. At the two higher temperatures, however, its surface stability is insufficient and a break occurs in the logarithmic relationship. This diagnosis is based on microscopic studies which show nothing but general oxidation at 1000 and 1100° F., but after about 1100 hr. at 1300° F. there is intergranular attack as well. In this case recrystallization and grain coarsening has also occurred.

### Acceptance Tests

When the stress-rupture characteristics of a given steel have been established, it is felt this test will provide a convenient means for determining the comparative high temperature characteristics of other steels of the same general type. For this purpose, relatively short tests of 200 to 300 hr. should be sufficient.

For example, it is believed logical to assume that if the logarithmic line, resulting from a plot of stress and fracture time, should lie above the one initially established, the second steel would possess the greater load-carrying ability. If, on the other hand, this line should fall below, then the load-carrying ability could certainly be inferred to be inferior.

The same considerations apply to an acceptance test. It is known that successive heats of steel of almost identical analysis and history will frequently differ greatly in creep characteristics. The present stress-rupture test should be able to distinguish quickly which of the steels will have unsatisfactory resistance at high temperature. Tests of 24 hr. duration may, in fact, be sufficient.

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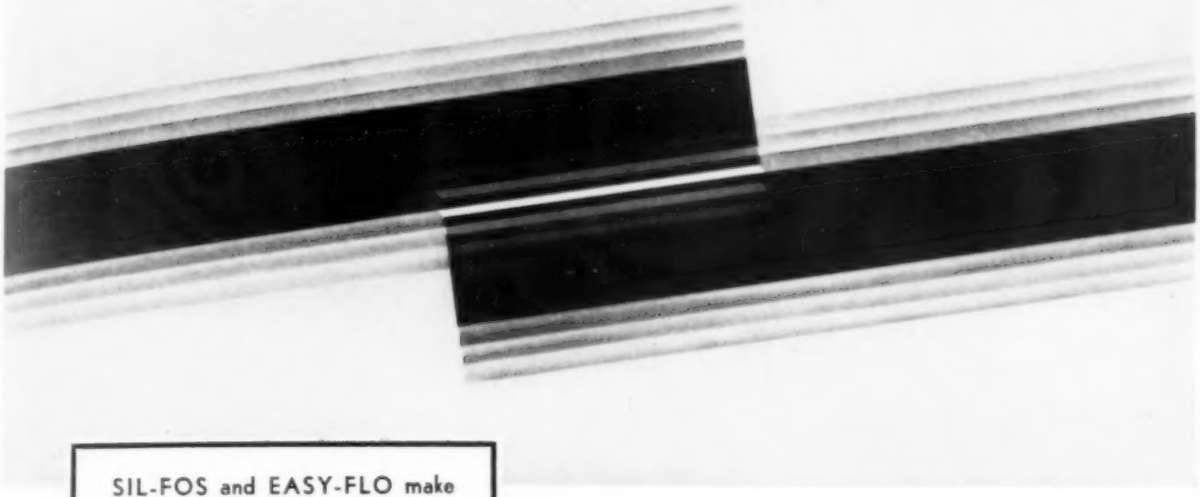

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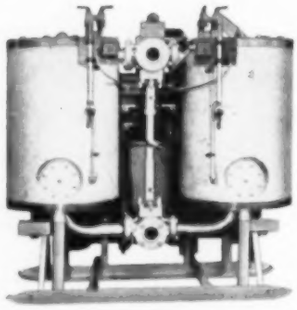

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# Cast Iron Gears

(*Continued from page 262*) carbides over the amount necessary for pearlite to decompose into diffused particles of graphite (by the addition of measured amounts of calcium silicide to the ladle)." These alloys have given good service in a number of gear forms, both big and little.

Pearlitic irons of this sort may readily have from three to five times the 14,000 psi. tensile strength of common gray iron samples cut from large castings. Brinell hardness is only moderately increased, ranging from 200 to 220 (instead of about 150), and therefore machinability is not impaired. Doubts as to its shock resisting capacity, held by some who put undue importance on the figures for elongation and reduction of area in the tensile test, are dispelled by service reports and also by (1) the high damping capacity of cast iron, which is a high degree of internal friction preventing resonance stresses from building up to dangerous proportions by converting the energy of vibration into heat and dispersing it; (2) the property known as crackless plasticity, of withstanding an occasional overstress without developing a fatigue crack; and (3) excellent resistance to repeated shock, as in the Stanton impact test.

Combining wear, toughness, strength, low coefficient of friction, dampening vibration, assuring uniform properties whether cast in light or heavy sections, and machining freely even at Brinell hardness values up to 300, Meehanite is therefore a useful and economical material for cast-to-form or cut gears, spur, bevel and worm. Such gears are giving excellent service in varied industries, including machine tools, steelworks equipment, overhead traveling cranes, heavy engineering machinery, paper and cement mills.

Where considerable shock is to be encountered, it is usual to use alloy steels of exceptional ductility. However, the impact strength of these special irons is distinctly superior to what might be inferred from the conventional tensile test bar data; in terms of actual service it has been able to withstand impact and shock equally as well as some of the most costly steel gears.

Specific installations include gears on main drives of rubber calender mills and plasticators, cold heading machines and briquetting machinery. Others where resistance to abrasive dusts is rather more important are gears for tumbling barrels, pug mills, concrete mixers and cement kilns. In these large gears the teeth are frequently chill cast, giving an outer case of generous depth and a Brinell hardness approaching 500, or teeth can be machined in soft state and flame hardened.

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# Authors' Page

**George F. Comstock**, who, as metallurgist for the Titanium Alloy Mfg. Co., has spent the past quarter of a century finding new properties and new uses for titanium, has been largely responsible for the development of titanium cyano-nitride for high chromium steels (page 269). The three years between Mr. Comstock's graduation from Columbia School of Mines in 1909 and his association with the Titanium Company in 1912 were spent in a vanadium smelter in Colorado, and in the plants of Maryland Steel Co. and Crucible Steel Co.

**Henry Christian Bigge** has been intimately connected with the practical end of steel making for his entire professional career, and is thus eminently fitted to trace the history of toolsteel. (The third of a series on this subject is the leading article in this issue, page 252.) Born and raised in Pittsburgh, Mr. Bigge attended Carnegie Institute of Technology from 1909 to 1912 and at the same time worked for Crucible Steel Co. of America. His next connection was with Carpenter Steel for three years, and his third and final with Bethlehem, where he has been superintendent of electric furnace and toolsteel departments since 1918.

University of Michigan's **A. E. White** and **C. L. Clark** have for several years been inseparable collaborators on research papers concerning various aspects of high temperature testing. Professor White has been at Michigan some 27 years, and is currently director of the department of engineering research. He is well known to ASM members as first president and founder member of the old American Society for Steel Treating. Clark, who studied under Professor White during the 20's and received his Ph.D. in 1928, is now an engineer in the department of engineering research.

Added to White and Clark is often found a third name attached to the Timken Roller Bearing Co.'s metallurgical staff. A case in point is the Western Metal Congress paper on the stress-rupture test, page 266. The third author, **Walter G. Hildorf**, chief metallurgical engineer for Timken since 1928, graduated from Michigan State College in 1915, worked for two years in the Copper Range Mines, and then returned to get a metallurgical engineering degree, meanwhile serving as instructor and assistant professor. In 1920 he quit teaching to spend the next eight years as chief metallurgist for Reo Motor Car Co.

Dropping his editorial blue pencil and pince-nez, **Ernest E. Thum** on two recent occasions demoted himself to the rank of reporter, and who shall blue-pencil the editor? First he visited the various copper and brass plants, coming back with an account of the copper-silicon alloys, the first part of which appears on page 258. Another time he attended a discussion conference on heat resisting alloys held by the Cleveland Chapter, took a few notes and produced the report found on page 276. Editor Thum (Colorado School of Mines '06), after ten years in the western smelters as an engineer for Anaconda, made a broad jump to the chair of metallurgy at University of Cincinnati. This was soon followed by his first venture into the editorial field as metallurgical editor of Chemical & Metallurgical Engineering. By the time METAL PROGRESS was formulated in 1930 and he became its first and only editor, he had served successively as head of the technical publicity department of Union Carbide & Carbon Corp. and as principal associate editor of The Iron Age.

George F. Comstock

Henry C. Bigge

C. L. Clark

Walter G. Hildorf

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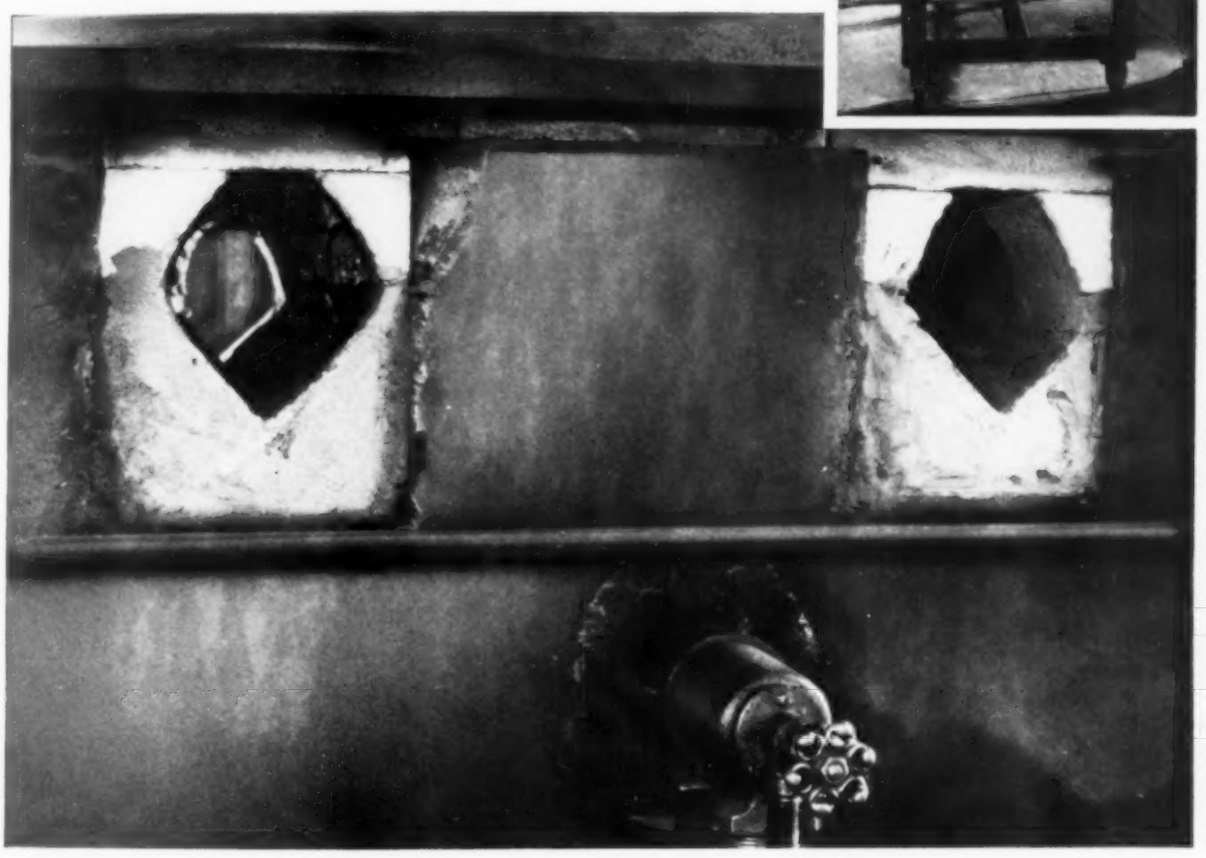

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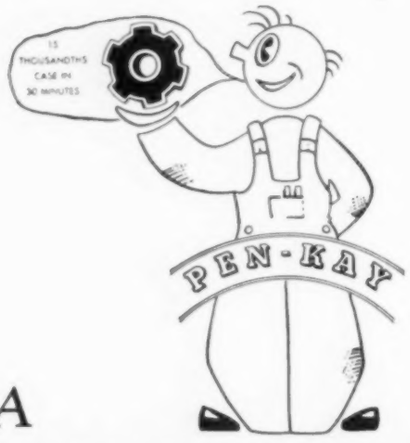


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# Distortion of Springs during heat treatment

By Maurice Bonzel

*Abstracted from Revue de Metallurgie, June and July, 1937*

CHANGES IN HEIGHT, NUMBER OF COILS, AND OTHER dimensional elements of springs during their necessary heat treatment is a matter which manufacturers would like to control. Permanent distortion resulting from hardening or annealing metal has been studied and was reported in *Revue de Metallurgie* in 1927 and 1931 by Portevin and Sourdillon, who worked with cylindrical specimens. Mr. Bonzel, the author of the articles abstracted and who is best known in America as author of a book on "Steel Wire, Its Manufacture and Properties," which has been translated and published here, is the operating head of a wire plant concerned with high carbon and alloy steels. His researches, whose results he has generously made public, are always related closely to mill problems, and in this case treat of precision springs tempered after forming.

The distortion of articles fabricated from cold-worked metal and finally quenched can be minimised by a preliminary anneal followed by a correction of the shape. This, however, is a rather clumsy and costly expedient, and heightens the dangers of scaling and decarburization. It is Mr. Bonzel's belief that the distortions follow laws which are not necessarily occult from human understanding, and that advantage may be taken of these laws, either to hold distortion within close limits or to compel it to complete the work of forming the article.

For the study of the phenomena he has devised the "stephograph," which is an electric furnace in which one end of a cold-twisted wire specimen may be held secure while the other end, free to move as distortion proceeds, actuates the pen which traces a graph on a suitably arranged cylindrical chart. The controlled factors are composition, metallographic state, degree and direction of cold work, and time and temperatures in the heating cycle.

The curves, studied properly in series, suggest fidelity to laws which do not seem too complex for practical use. These facts seem clear:

1. Distortion begins near ambient temperature, and continues up to full anneal.

2. Distortion occurs chiefly during heating, and persists through the cooling range, whatever its character.

3. Reheating does not cause further distortion.

4. With uniform composition, distortion varies with the metallographic state. (*Cont. on page 318*)

# PAGE *Hi-tensile "F"*

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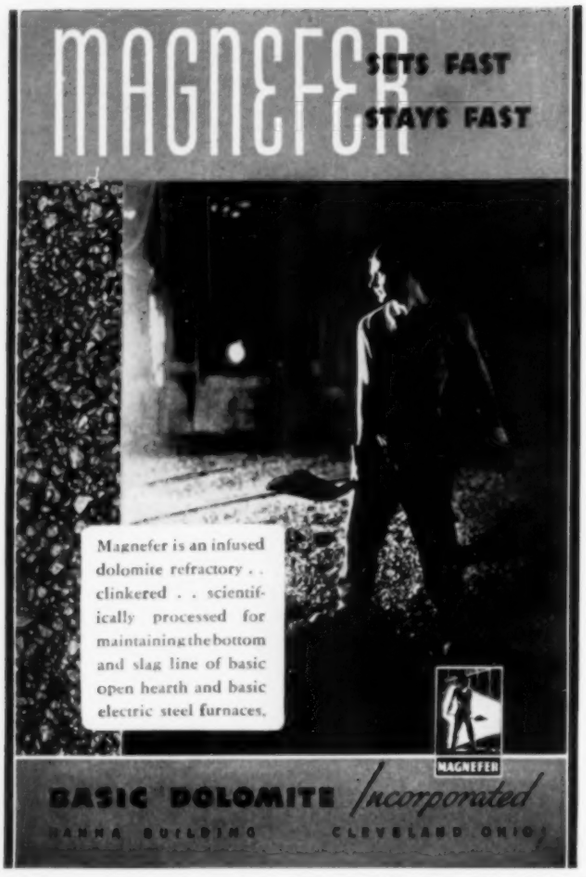
# PAGE *Welding* WIRE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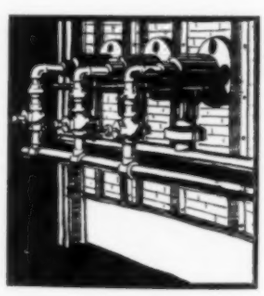
# Distortion of Springs

(*Continued from page 314*)

5. There is no proportion between amount of cold work and degree of distortion on heating. A small amount of cold twist may result in a large amount of untwisting in the furnace, or a high degree of cold twist may result in very little untwisting, or even in a further twisting in the same direction.

6. The speed of heating has little or no effect on the result.

When a wire is twisted beyond its yield point equilibrium is established between two opposing sets of couples; those in the center tend to untwist the wire, and those at the surface act as brakes. When heat is applied, the first movement, regardless of composition or amount of twist, is in the direction of untwisting, and, as the temperature mounts, there may be further untwisting, or twisting back in the original direction, depending on the metal and its metallographic state.

With steels of the hardening range, in which pearlite is a large element, the dominating factor is the state of the cementite, whether coarsely or finely laminated, or spheroidal. If a specimen is twisted and then slightly untwisted, the shape of the curve will be greatly affected, and likewise if, after twisting, a specimen is lightly drafted and a new distribution of stress thereby secured.

With the state of the cementite dominant, it is clear that the heat treatment next preceding the hardening cycle is of utmost importance. Mr. Bonzel suggests that in making precision springs it is worth while not only to control the metallographic state but even to run "shoe-strings" before the final fabrication. He asserts that he has been able not only to hold distortion within unusually close limits, thereby cutting rejections and costs, but also to use distortion as a part of the fabricating scheme. As a concrete example he offers the case of rings formed of cold worked metal, whose ends, because of the resilience of the metal, can never be brought squarely together. Under controlled conditions the final quench and temper will bring these ends exactly into contact.